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CONSTRUCTION OF EDUCATIONAL THEORY MODELS.
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THIS STUDY DELINEATED MODELS WHICH HAVE POTENTIAL USE IN GENERATING EDUCATIONAL THEORY. A THEORY MODELS METHOD WAS FORMULATED. BY SELECTING AND ORDERING CONCEPTS FROM OTHER DISCIPLINES, THE INVESTIGATORS FORMULATED SEVEN THEORY MODELS. THE FINAL STEP OF DEVISING EDUCATIONAL THEORY FROM THE THEORY MODELS WAS PERFORMED ONLY TO THE EXTENT REQUIRED TO ESTABLISH THE CONSTRUCTED MODELS AS EDUCATIONAL THEORY MODELS. EDUCATIONAL THEORY MODELS WERE FORMULATED FROM THE FOLLOWING CONCEPTS--(1) SOCIAL SCIENCE GRAPH THEORY, (2) GENERAL SYSTEMS THEORY, (3) AGRICULTURAL ECONOMIC THEORY, (4) PHARMACOLOGY AND PHARMACOGENETICS, (5) QUANTUM THEORY, (6) THEORY OF LOCAL AND COSMOPOLITAN INFLUENTIALS, AND (7) INFORMATION THEORY. (JM)

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CONSTRUCTION OF EDUCATIONAL THEORY MODELS

Cooperative Research Project No. 1632

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The Ohio State University
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INTRODUCTION

The empiricist's rebellion against the speculative era which led to the discounting of all theory and the devotion of most energy to fact finding and the improvement of verification techniques is past. There is recognition that theory can be other than mere speculation and, what is more important, that it is practical. The choice, therefore, is not between theory and no theory, but between adequate and inadequate theory.

The recognition that theory can be other than mere speculation is evidenced in dissatisfaction with the sense of 'theory' as contained in expressions as 'It is a fact and not a theory.' All theory cannot be separated from fact. There is descriptive as well as prescriptive theory. For example, Tolmanian learning theory pertains to matters of fact, while Deweyian educational theory pertains essentially to matters which ought to be. Tolman describes what one does do as he learns, while Dewey prescribes what would constitute good learning. Compare these two quotations:

> The present writer starts from the doctrine of Adams and Lewin, but asserts that, for the problem of learning, the important relations in the "psychobiological fields" are "sign relations". "Learning" he would describe as the new formation, or the reformation, of "sign-gestalts" within the larger psychobiological fields. The theory is therefore to be designated as a "sign-gestalt" theory.[1]
>
> This book represents the conviction that the needed steadying and centralizing factor is found in adopting as the end of endeavor that attitude of mind, that habit of thought, which we call scientific.[2]
>
> . . . .

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[1] E. C. Tolman, "Theories of Learning," in Comparative Psychology, edited by F. A. Moss, New York: Prentice-Hall, 1934, p. 392.

[2] Dewey, How We Think, New York: D. C. Heath and Company, Revised edition, 1933, p. v.

> Scientific method includes . . . all the processes by which the observing and amassing of data are regulated with a view to facilitating the formation of explanatory conceptions and theories. These devices are all directed toward selecting the precise facts to which weight and significance shall attach in forming suggestions or ideas.[3]

Tolman's words describe learning to be the giving to one field feature significance in terms of another. Dewey's words go beyond Tolman's and prescribe that only scientific significance should be given. Dewey takes a philosophic stand, while Tolman takes only a scientific one. To assert the value of science, it is necessary to take a stand beyond science. Tolman's theory is empirical, while Dewey's is essentially non-empirical. Tolman does science and Dewey philosophy, but both are theoreticians.

The recognition that theory is practical is evidenced in dissatisfaction with the sense of 'theory' as contained in expressions as 'It might be adequate theory, but it is impractical.' Theory, whether prescriptive or descriptive, is practical. Prescriptive theory results in ends or gives direction to practice. Descriptive theory results in means or gives control to bring about the kind of practice wanted. In other words, prescriptive theory marks off the practice to be and descriptive theory lets it come into being. In the context of engineering, Howland indicated the practicality of descriptive theory:

> The scientist develops theory, and the engineer uses it to satisfy the needs of society. The theory the engineer uses may consist of explicit, formal statements of relationships, such as Ohm's or Newton's laws, or it may be implicit and private, developed as a result of experience. It is difficult, however, to conceive of an

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[3] *Ibid.*, p. 171.

> engineer practicing as a professional without some idea of how the phenomena he is dealing with are related. If his ideas are right his practice will be successful; if they are not, he may get into trouble. The choice, then, is not between theory and lack of it, but between good theory and bad.[4]

From the quotation, it is apparent that Howland takes prescriptive theory to be embodied in the needs of society. Successful practice would result from the engineer's bringing about of these needs through the adequate descriptive theory he possesses. Stated simply, his ideas as to the relationship of means and ends to be attained are right.

Successful teaching practice is wanted by those of us who consider education to be one of the most significant factors in the life of our society. Since successful teaching practice only results from adequate theory about the phenomena the teacher has to deal with--behavior in the institutional setting called 'the school', what is wanted is adequate educational theory. Often such theory is had, but only implicitedly. As a result of experience, a teacher has developed ideas about education that are successful in practice. However, unless such ideas are made explicit and so available for transmission within the teacher education process, the future teacher only can be set forth to experience with the hope that his practice will turn successful as his ideas about education become adequate. Recognizing the need for explicitedly stated adequate educational theory, we undertook this research project.

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[4] Daniel Howland, "Engineering in Interdisciplinary Research," in Journal of Engineering Education, Vol. 52, No. 10, 1962, p. 664.

In our endeavor we restricted ourselves to the development of descriptive educational theory which was free of commitment to any given educational ends or objectives. We attempted to develop value-open empirical educational theory rather than one closed off in terms of its inclusion of a given philosophic educational theory. Nor were we concerned to develop philosophic educational theory. Such a restriction did not mean that we could avoid the philosophic issue. Philosophic sophistication must be brought to bear, if a value-open empirical educational theory is to be possible. Value-open implies all possibilities with respect to values. An adequate value-open empirical educational theory must incorporate in an explicit manner possibilities with respect to educational objectives. To do so, one must know philosophy. Indeed the educational theorist must be prepared in both the scientific and humanistic dimensions.

The restriction to the development of a value-open empirical educational theory came about because we thought a way for such theorizing could be formulated in terms of a procedure used in developing other value-open empirical theory. Models have been used successfully in developing adequate theory in the physical, biological, and behavioral sciences. A way of educational theorizing through models was formulated. Section I of this report presents the formulation of the theory models method. The metatheory--theory of educational theorizing--is not inductive in method. One does not begin with observable data and work toward a system of precise concepts. Rather the theory models approach is retroductive. One begins with concepts from other fields. This beginning point establishes the interdisciplinary nature of the theory models approach. Then one formulates a theory model, i.e. one selects among the concepts and orders those selected. The final step is the devising of the educational theory from the theory model. Section II, which presents the results of our survey of recent literature dealing with the use of models for the study of various aspects of education, indicates that the theory models approach has not formed the metatheoretical background of the ongoing endeavor of educational theorizing.

The final section, Section III, presents the educational theory models which we constructed. Although in this project our research to develop adequate value-open empirical educational theory involved only the construction of theory models and not the final step of devising educational theory, nevertheless some tentative educational theorizing was done. This was done to establish the constructed theory models as educational theory models, since there is no exclusively a priori way of doing so. The tentative educational theorizing is included, along with the theory models, in this final section.

SECTION I

METATHEORY: RETRODUCTION, MODELS, AND EDUCATIONAL THEORIZING

WAYS OF INQUIRING*

by Elizabeth Steiner Maccia

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*This paper first appeared as Occasional Paper 62-107, The Bureau of Educational Research and Service, The Ohio State University, 1962.

"I should see the garden far better," said Alice to herself, "if I could get to the top of that hill: and here is a path that leads straight to it--at least no, it doesn't do that--but I suppose it will at last. But how curiously it twists! It's more like a corkscrew than a path!"

> The sole cause and root of almost every defect in the sciences is this, that whilst we falsely admire and extol the powers of the human mind, we do not search for its real helps.[1]

The search for the real helps for the human mind in its endeavor to produce science without defect is one aspect of the general search for ways of inquiring which would result in knowledge. Knowledge consists of true meanings in the various realms. For example, man is knowledgeable about the realm of instances we designate 'the physical,' when he relates these instances through concepts in such a manner that there is possibility for control. Such knowledge is set forth in the subject matter we call 'the Physical Sciences.' Boyle's law, $PV = K$, is a statement within the Physical Sciences that relates instances through the concepts of pressure and volume presented in an inverse relation to one another, so that there is a possibility of controlling the pressure by means of the volume and vice versa.

What, then, are the ways of inquiring that result in scientific knowledge?

> There are and can exist but two ways of investigating and discovering truth. The one hurries on rapidly from the senses and particulars to the most general axioms; and from them as principles and their supposed undisputable truth derives and discovers the intermediate axioms. This is the way now in use. The other constitutes its axioms from the senses and particulars, by ascending continually and gradually, till it finally arrives at the most general axioms, which is the true, but unattempted way.[2]
>
> Each of these two ways begins from the senses and particulars, and ends in the greatest generalities. But they are immeasurably different; for the one merely touches cursorily the limits of experiment, and particulars, whilst the other runs duly and regularly

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[1] Bacon, Novum Organum, Summary of the Second Part, Aphorism 9.

[2] Ibid., Aphorism 19.

> through them; the one from the very outset lays down some abstract and useless generalities, the other gradually rises to those principles which are really the most common in nature.[3]

In the above statements, Bacon offered an answer to our question. There can be only two ways of inquiring, the deductive and the inductive way. In the deductive way, there is a leading from. One begins with the most general axioms[4] and draws out other less general axioms. In the inductive way, there is a leading to. One begins with observation of instances and from them constructs less general axioms; then from these less general axioms, other more general axioms are constructed. However, induction is the only way that results in scientific knowledge.

The deductive way is the way of inquiring in mathematics. Consider Euclidean geometry. From postulates, all the theorems making up this body of mathematical knowledge are derived by a process of reasoning. Because rules of deductive logic are followed; it can be said that, given the postulates, the theorems are certain--they necessarily follow from the postulates. Impressed by this certainty--

> Considering that among all those who have previously sought truth in the sciences, mathematicians alone have been able to find some demonstrations, some certain and evident reasons.[5,6]

---

[3] Ibid., Aphorism 22.

[4] The term, 'axiom,' in the context of mathematics means a self-evident proposition: one not requiring demonstration but assented to as soon as stated. In the context of Bacon's thought, it means an empirical generalization--a generalization about experience--such as Boyle's law.

[5] Descartes, Discourse on Method, trans. by L. J. Lafleur, New York: The Liberal Arts Press, Second (revised) edition, 1956, p. 13.

[6] Notice that Descartes equates all of knowledge with scientific knowledge. In this paper, scientific knowledge is taken to be empirical knowledge, knowledge about experience. Thus, formal knowledge--non-applied logic and mathematics--is not taken to be scientific knowledge.

Descartes ignored Bacon's answer; so, also in the seventeenth century, he set forth the mathematical way, deduction, as the way of inquiring that would result in scientific knowledge.

> Those long chains of reasoning, so simple and easy, which enabled the geometricians to reach the most difficult demonstrations, had made me wonder whether all things knowable to men might not fall into a similar logical sequence. If so, we need only refrain from accepting as true that which is not true, and carefully follow the order necessary to deduce each one from the others, and there cannot be any propositions so abstruse that we cannot prove them, or so recondite that we cannot discover them.[7,8]

The difficulty, of course, is the lack of a decision procedure in regard to acceptance of a generalization or generalizations as true and as the postulates of our system. So it came to pass that other systems with different self-evident truths as postulates, for example Spinoza's, were set forth. It was simply a matter of time until there was an awakening from this seventeenth century rationalistic dogmatic slumber.

In our own century, Dewey expressed this awakening by returning to the Baconian answer.

> Pure reasoning as a means of arriving at truth is like the spider who spins a web out of himself. The web is orderly and elaborate, but it is only a trap. . . . True method, that which Bacon would usher in, is comparable to the operations of the bee who, like the

---

[7] Ibid., pp. 12-13.

[8] "Then, when I wanted to descend to particulars, it seemed to me that there were so many different kinds that I believed it impossible for the human mind to distinguish the forms or species of objects found on earth from an infinity of others which might have been there if God had so willed. It thus appeared impossible to proceed further deductively, and if we were to understand and make use of things, we would have to discover causes by their effects and make use of many experiments." (Ibid., p. 41.) These statements indicate that Descartes had certain reservations about sole reliance upon the deductive way of inquiring.

> ant, collects material from the external world, but unlike that industrious creature attacks and modifies the collected stuff in order to make it yield its hidden treasure.[9]

In How We Think, Dewey goes on to tell us the modes of attack and modification:

> Scientific method includes . . . all the processes by which the observing and amassing of data are regulated with a view to facilitating the formation of explanatory conceptions and theories. These devices are all directed toward selecting the precise facts to which weight and significance shall attach in forming suggestions or ideas. Specially, this selective determination involves operations of (1) elimination by analysis of what is likely to be misleading and irrelevant, (2) emphasis of the important by collection and comparison of cases, and (3) deliberate construction of data by experimental variation.[10]
>
> Many volumes would be required to describe in detail all the methods that investigators have developed in various subjects for analyzing and restating the facts of ordinary experience so that we may escape from capricious and routine suggestions and may get the facts in such a form and in such a light (or context) that exact and far-reaching explanations may be suggested in place of vague and limited ones. But these various devices of inductive inquiry all have one goal in view: the indirect regulation of the function of suggestions, or formation of ideas; and, in the main, they will be found to reduce to some combination of the three types of selecting and arranging subject matter just described.[11]

In Dewey's expression of the scientific method, the way of inquiring that leads to scientific knowledge, the emphasis is upon the regulation of data in order to form theory. Nevertheless, he did recognize that the suggestion from which the theory arose did not have its source in data.

> The facts or data set the problem before us, and insight into the problem corrects, modifies, expands the suggestion that

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[9] Dewey, Reconstruction in Philosophy, Boston: The Beacon Press, Enlarged edition, 1948, p. 32.

[10] New York: D. C. Heath and Company, Revised edition, 1933, p. 171.

[11] Ibid., pp. 177-178.

> originally occurred. In this fashion the suggestion becomes a definite supposition, or, stated more technically, a hypothesis.[12]
>
> The data at hand cannot supply the solution; they can only suggest it. What, then, are the sources of suggestion? Clearly, past experience and a fund of relevant knowledge at one's command.[13]

Unfortunately, this recognition did not form a part of his explicated way of inquiring, nor did it modify his acceptance of the Baconian answer.

The literature abounds with statements about scientific inquiry couched in Baconian terminology. Consider the following statements of Ralph W. Tyler:

> . . . when Dearborn and others developed instruments which identified eye movements in reading, they found that the reader normally focused his eyes on a whole word or several words at a time. Only when in doubt about the word or phrase did he fix his attention on a syllable or an individual letter. The reader who read rapidly and with great comprehension was found to use a wide span of recognition, fixing his eyes on only three or four points along each line of type. The poor reader who read slowly and with limited comprehension had a small span of recognition, looking at only one word or a part of a word at a time.
>
> From these observations a theory was built which explained the mature reader's behavior as perception and interpretation of what was perceived. He was able to perceive fairly large units of the printed language in one glance and to interpret them.[14]

But more, even an inquiry training program has a Baconian framework. J. Richard Suchman speaks of his program as one in which "the learner actively gathers and processes data from which the concepts emerge."[15] His schema for inquiry includes stages for episode analysis and determination of relevance and conditions which parallel Dewey's devices of inductive inquiry. The final stage is induction of relational constructs.[16] As Dewey, Suchman recognizes an element beyond the Baconian framework when he states:

---

[12] Ibid., pp. 109-110.

[13] Ibid., p. 15.

[14] "Specific Contributions of Research to Education," in Theory Into Practice, Vol. 1, No. 2, 1962, pp. 77-78.

[15] "Inquiry Training: Building Skills for Autonomous Discovering," in Merrill-Palmer Quarterly of Behavior and Development, Vol. 7, No. 3, 1962, p. 148.

> Intuition and creativity are far more critical for optimal behavior in Stage III than in the preceding two . . . .[17]

Another aspect of knowledge, its systematic nature, has led to a recognition that deduction must be accepted as at least a part of the way of inquiring that results in scientific knowledge.

> But even a meaningful scale will not help to develop new information if we do not attempt to build and integrate our knowledge. It is true that the fragmentary nature of much educational research can be attributed in part to the inference process, but the failure of research workers to relate their research to a sound theoretical base is also partly responsible. Too much of it is still on the "hunch" or "let's try this and see what happens" basis, without the carefully thought-through rationale that ties a research study to its theoretical underpinnings and to previous research findings.[18]

Deduction would be the way of tying a research study to theoretical underpinnings and to previous research findings. The hypothesis or hypotheses being checked out in a given research study might be related to a theory (be deduced from statements in the theory); and might be related to other research findings, because the latter are integrated by theory.

While Krathwohl still retains an element beyond induction and deduction,

> Certainly some portion of our studies should continue to be of the "hunch" type. From such experiments we often start a new research direction.[19]

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[16] Ibid., pp. 158-161.

[17] Ibid., p. 161.

[18] David R. Krathwohl, "The Scope of the Research Problem," in Theory Into Practice, Vol. 1, No. 2, 1962, p. 101.

[19] Ibid.

others attempt to make deduction and induction the sole ways of inquiring that result in scientific knowledge. To illustrate, Hillway summarizes the following description of inquiry

> My first note-book was opened in July 1837. I worked on true Baconian principles, and without any theory collected facts on a wholesale scale, more especially with respect to domesticated productions, by printed enquiries, by conversation with skillful breeders and gardeners, and by extensive reading. . . . I soon perceived that selection was the keystone of man's success in making useful races of animals and plants. But how selection could be applied to organisms living in a state of nature remained for some time a mystery to me.
>
> In October, 1838, that is fifteen months after I had begun my systematic inquiry, I happened to read for amusement 'Malthus on Population,' and being well prepared to appreciate the struggle for existence which everywhere goes on from long-continued observation of the habits of animals and plants, it at once struck me that under these circumstances favourable variations would tend to be preserved, and unfavourable ones to be destroyed. The result of this would be the formation of new species. Here then I had at last got a theory by which to work . . . .[20]

in these words:

> Thus Darwin used both inductive and deductive reasoning to arrive at his final conclusions. This is a good example of how modern research works.[21]

This view of the logic of science is schematized in Diagram 1.

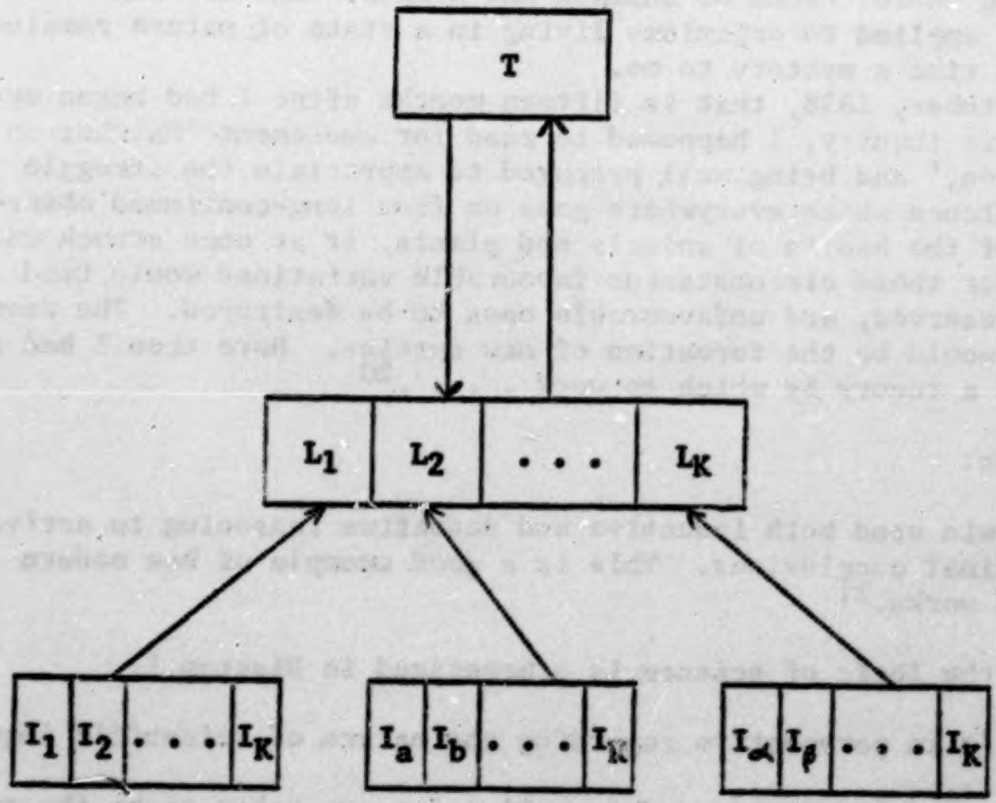
A shift in perspective regarding the nature of scientific inquiry obtains where model-making and data collection are taken to be the two aspects of scientific method.[22] Bross sets forth the relationship between these two

---

[20] Francis Darwin, ed., The Life and Letters of Charles Darwin, 2 Vols., New York: D. Appleton and Co., 1899, Vol. I, p. 68.

[21] Tyrus Hillway, Introduction to Research, Boston: Houghton Mifflin Company, 1956, p. 11.

[22] Irwin D. J. Bross, Design for Decision, New York: The Macmillan Company, 1953, p. 174.


T
L_1
L_2
. . .
L_K
I_1 I_2 . . . I_K
I_a I_b . . . I_K
I_α I_β . . . I_K

'T' stands for Theory
'L' stands for Experimental Law
'I' stands for Instance
'↑' stands for Induction
'↓' stands for Deduction

Diagram 1

aspects in the following figure:

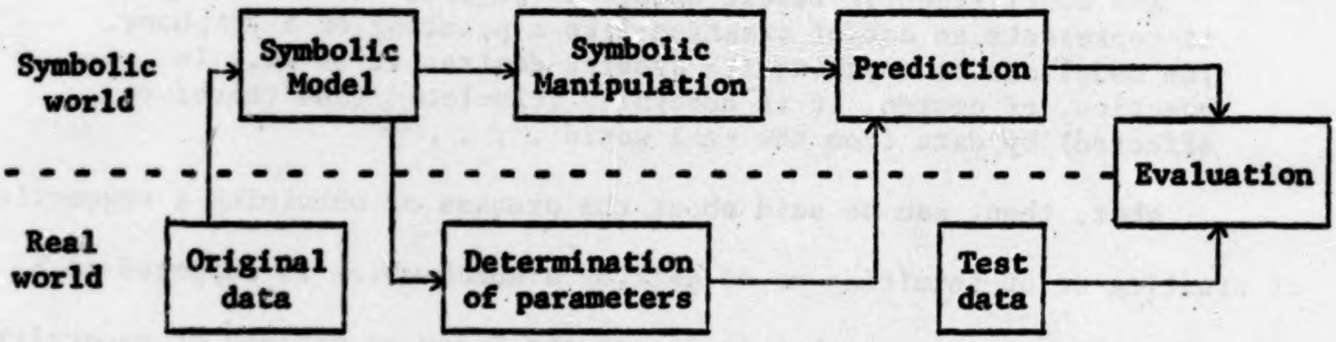

Symbolic world
Symbolic Model
Symbolic Manipulation
Prediction
Evaluation
Real world
Original data
Determination of parameters
Test data

Fig. 10.01[23]

The shift I am referring to is not the change in terminology where 'theory' becomes 'model,' 'experimental law' becomes 'prediction,' and 'instance' becomes 'data;' rather it consists in the discernment of what are taken to be two dimensions of induction.[24] Through the inductive process, one derives a model from data; and through inductive inference, one evaluates the model in terms of data. The model is thought checkable, because predictions are deduced through symbolic manipulation of the model and these predictions have been given specification by means of parameters, i.e. they have been made measurable. This shift provides a basis for the delineation of a third component of the way of inquiring that results in scientific knowledge.

It has been seen that Dewey, Suchman, and Krathwohl point to a component beyond induction and deduction. Bross, too, qualifies the view that theory arises solely through an inductive process.

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[23] Ibid.

[24] Buchdahl in The Australasian Journal of Philosophy, Vol. 34, No. 3, 1956, p. 168, terms the obtaining of the theory 'the inductive process' and the checking of the theory 'the inductive inference.'

> The model [theory] itself should be regarded as arbitrary; it represents an act of creation like a painting or a symphony. The model can be anything its creator desires it to be. In practice, of course, it is generally stimulated (and therefore affected) by data from the real world . . . .[25]

What, then, can be said about the process of obtaining a suggestion or of creating or of intuiting or of getting a hunch which is supposed to be the source of theory? To say that it is not the Baconian process of generalizing from particulars, whether they be instances or lesser generalizations, or it is not the deductive process does not answer the question.

It was Peirce who contributed to an answer to this question. Peirce recognized a third kind of reasoning--abduction or retroduction.[26] He delineated a third component in the scientific way of inquiring.

> These three kinds of reasoning are Abduction, Induction, and Deduction.[27]

It was through retroduction that theory arose.

> . . . neither Deduction nor Induction contributes the smallest positive item to the final conclusion of the inquiry. They render the indefinite definite; Deduction explicates; Induction evaluates: that is all. Over the chasm that yawns between the ultimate goal of science and such ideas of Man's environment as, coming over him during his primeval wanderings in the forest, while yet his very notion of error was of the vaguest, he managed to communicate to some fellow, we are building a cantilever bridge of induction, held together by scientific struts and ties. Yet

---

[25] _Op. cit_., p. 174.

[26] Peirce uses the terms 'abduction' and 'retroduction' interchangeably.

[27] _Collected Papers_, ed. by Hartshorne and Weiss, Cambridge: Harvard University Press, 5.145.

> every plank of its advance is first laid by Retroduction alone . . . and neither Deduction nor Induction contributes a single new concept to the structure.[28]

Or to put the matter differently, Peirce recognized three main stages to inquiry:

> The inquiry begins with pondering these[29] phenomena in all their aspects, in the search of some point of view whence the wonder shall be resolved. At length a conjecture arises that furnishes a possible Explanation, by which I mean a syllogism exhibiting the surprising fact as necessarily consequent upon the circumstances of its occurrence together with the truth of the credible conjecture as premises. . . . The whole series of mental performances between the notice of the wonderful phenomenon and the acceptance of the hypothesis . . . I reckon as composing the First Stage of Inquiry. Its characteristic formula of reasoning I term Retroduction . . . .
>
> . . . .
>
> Retroduction does not afford security. The hypothesis must be tested.
>
> This testing to be logically valid, must honestly start . . . with examination of the hypothesis, and a muster of all sorts of conditional experiential consequences which would follow from its truth. This constitutes the Second Stage of Inquiry. For its characteristic form of reasoning our language has, for two centuries, been happily provided with the name Deduction.
>
> . . . .
>
> The purpose of Deduction, that of collecting consequents of the hypothesis, having been sufficiently carried out, the inquiry enters upon its Third Stage, that of ascertaining how far those consequents accord with Experience, and of judging accordingly whether the hypothesis is sensibly correct, or requires some inessential modification, or must be entirely rejected. Its characteristic way of reasoning is Induction.[30]

To clarify further the difference between retroduction and induction, note that induction is limited to one dimension of the two noted earlier.

---

[28] Values in a Universe of Chance, ed. by Philip P. Wiener, New York: Doubleday Anchor Books, 1958, pp. 370-371.

[29] "Of some surprising phenomenon, some experience which either disappoints an expectation, or breaks in upon some habit of expectation of inquisiturus . . ." (Ibid., p. 367.)

[30] Ibid., pp. 367-369.

It has to do only with the evaluation of theory--the inductive inference.

> Induction may be defined as an argument which proceeds upon the assumption that all the members of a class or aggregate have all the characters which are common to all those members of this class concerning which it is known, whether they have these characters or not; or, in other words, which assumes that that is true of a whole collection which is true of a number of instances taken from it at random. This might be called a statistical argument.[31]

It has nothing to do with the generation of theory--the supposed inductive process.

> . . . the absence of knowledge is either whether besides the objects which, according to the premisses, possess certain characters, any other objects possess them; or, whether besides the characters which, according to the premisses, belong to certain objects, any other characters not necessarily involved in these belong to the same objects. In the former case, the reasoning proceeds as though all the objects which have certain characters were known, and this is induction; in the latter case, the inference proceeds as though all the characters requisite to the determination of a certain object or class were known, and this is hypothesis.[32,33]

A "corkscrew" has led us to retroduction, deduction, and induction as helps to the mind in developing science without defect or characterizations of objects which permit control. Through retroduction, one devises characterizations--statements or theory about objects. Through deduction, one clarifies and completes such characterizations. Finally, through induction, one determines the objects falling within the range of the characterization. Retroduction devises, deduction explicates, and induction evaluates.

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[31] Ibid., pp. 45-46.

[32] Ibid., p. 44.

[33] Peirce uses the term 'hypothesis' to indicate the result of hypothetic thinking, and such thinking is what he calls 'retroduction' or 'abduction.'

However, has enough been said about retroduction? Has an answer been given to the question as to the process of forming theory? Among others, Dewey posed the question through statements such as the following:

> Projection, invention, ingenuity, devising come in for that purpose /setting forth suggestions/. The data arouse suggestions and only by reference to the specific data can we pass upon the appropriateness of the suggestions. But the suggestions run beyond what is, as yet, actually given in experience. . . .
>
> In this sense, a thought is creative,--an incursion into the novel.[34]

Peirce marked off the process as retroduction. The retroducing of retroduction has been accomplished. Yet he still speaks of retroduction in this way:

> The abductive suggestion comes to us like a flash. It is an act of insight, although of extremely fallible insight. It is true that the different elements of the hypothesis were in our minds before: but it is the idea of putting together what we had never before dreamed of putting together which flashes the new suggestion before our contemplation.[35]

No longer do we completely speak of deduction and induction in words which indicate lack of explication; namely 'intuition,' 'insight,' 'hunch,' 'creativity,' 'invention,' etc. The explication of retroduction largely remains to be done.

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[34] Democracy and Education, New York: The Macmillan Co., Paperback edition of the 1916 edition, 1961, p. 158.

[35] Collected Papers, 5.181.

MODELS AND THE MEANING OF 'RETRODUCTION'*

by Elizabeth Steiner Maccia

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*This paper first appeared as Occasional Paper 62-110, The Bureau of Educational Research and Service, The Ohio State University, 1962.

"I'm sure I didn't mean--" Alice was beginning, but the Red Queen interrupted her impatiently.

"That's just what I complain of! You *should* have meant! What do you suppose is the use of a child without any meaning?"

A help to the mind in developing science without defect which has no, or little, stated meaning surely would lead to supposition regarding its use. I have laid claim to retroduction as a help in devising theory.[1] Retroduction, therefore, must be explicated. The indefinite must be made definite.

Peirce's discussion of retroduction included reference to a point of view that would resolve the wonder arising from pondering phenomena or objects. The point of view allows setting forth a conjecture characterizing the objects.[2] But what is meant by a 'point of view' and how does it relate to the conjecture? A nineteenth century physicist, Heinrich Hertz, indicated the context wherein an answer is to be sought by drawing attention to models.

> We form for ourselves images or symbols of external objects; and the form which we give them is such that the necessary consequents of the images in thought are always the images of the necessary consequents in nature of the things pictured. In order that this requirement may be satisfied, there must be a certain conformity between nature and our thought. Experience teaches us that the requirement can be satisfied, and hence that such a conformity does in fact exist. When from our accumulated previous experience we have once succeeded in deducing images of the desired nature, we can then in a short time develop by means of them, as by means of models, the consequences which in the external world only arise in a comparatively long time, or as the result of our own interposition.[3]

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[1] See "Ways of Inquiring," the first paper in this section.

[2] Values in a Universe of Chance, ed. by Phillip P. Wiener, New York: Doubleday Anchor Books, 1958, p. 367.

[3] The Principles of Mechanics, trans. by D. E. Jones and J. T. Walley, London: Macmillan and Co., 1899, p. 1.

But the context marked off by Hertz needs sorting about, if through the concept of model we are to say anything significant of retroduction. 'Model' has come to have many meanings some of which have nothing, or little, to do with the developing of science without defect. For example, a book entitled Mathematical Models contains 278 pages setting forth directions for constructing physical objects which are taken to be models demonstrative of mathematics. To illustrate, one is told how to construct the Galton Quincunx which demonstrates the binominal distribution.[4] Models demonstrative of science also can be constructed. The familiar friend of school boys, the Cartesian diver, is numbered among these. Indeed the category of demonstrative models includes many of the audio-visual devices of the educator. Of course, one might say that such models have a little to do with the development of science. They might well provide scientific understanding, and so the occasional professor who might develop science.[5] The first sorting, then, is in terms of the domain of the logic of science. Demonstrative models are of little interest here.

Within the domain of the logic of science, there are also many meanings of 'model.' Furthermore, there is controversy as to what meaning or meanings are adequate. Consider that some would use 'theory' and 'model' interchangeably. H. Kacser states as much:

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[4] H. Martyn Cundy and A. P. Rollett, Mathematical Models, Oxford: Claredon Press, Second edition, 1961, pp. 217-219.

[5] The following interesting footnote in the book might substantiate in part such a claim: "There is a beautiful collection of polyhedral models in wire and cardboard at Winchester College. These were made by three boys, F. J. Dyson, M. S. and H. C. Longuet-Higgins, two of whom have later become university professors." Ibid. p. 13.

> . . . all models, theories, laws, and hypotheses have the same logical status . . . .[6]

Herbert Simon assumes as much. He wrote a series of essays in which he

> tried to set forth a consistent body of theory of the rational and nonrational aspects of human behavior in a social setting.[7]

Then he published them under the title, 'Models of Man.'[8] Others would warn against such identification, and even assert that it is unnecessary.

> The first danger is that theory will be identified with a model for it, so that the objects with which the model is concerned . . . will be supposed actually to be the same as the theoretical concepts of the theory. . . . Thinking of scientific theories by means of models is always as-if thinking; hydrogen atoms behave (in certain respects) as if they were solar systems each with an electronic planet revolving round a protonic sun. But hydrogen atoms are not solar systems; it is only useful to think of them as if they were such systems if one remembers all the time they are not.[9]

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[6] "Kinetic Models of Development and Heredity," in Models and Analogues in Biology, Symposia of the Society for Experimental Biology, Number XIV, Cambridge: The University Press, 1960, p. 15.

[7] Models of Man, New York: John Wiley & Sons, Inc., 1957, p. vii.

[8] Op. cit.

[9] R. B. Braithwaite, Scientific Explanation, Cambridge: University Press, 1953, p. 93.

> The first unnecessary use of "model" is a synonym for "theory."[10]

A second sorting is called for in regard to theory and model.

Brodbeck's analysis suggests that some theories are called 'models,' because they have certain characteristics; and she is quite right in asserting that these characteristics are found to hold for any theory.

> . . . uncertainty, selection, idealization, and quantification are characteristic to a greater or lesser degree of most worthwhile theories.[11]

Furthermore, I agree with her rhetorical query:

> What then is gained, except unnecessary confusion, by calling theories which share in some or all of these characteristics "models"?[12]

Yet there is a sense in which 'theory' is synonymous with 'model.' There is another characteristic that furnishes the basis for equivalence of logical status.

The distinction between being a model of and being a model for will furnish such a basis. To be a model of is to represent something, and to be a model for is to be represented in something. A common sense context will help to clarify what I have in mind. Consider a young woman who is hired by the Powers' Agency as a model.

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[10] M. Brodbeck, "Models, Meaning, and Theories," in Symposium on Sociological Theory, ed. L. Gross, Illinois: Row Peterson and Company, 1959, p. 381.

[11] Ibid., p. 383.

[12] Ibid.

The assumption is that the reason for her employment is her representation of the ideal in figure and manner. She is a model of the ideal. The ideal in this case might be a tendency toward the real, a statistical norm, although cursory observation on my part would indicate not. She in turn becomes a model for other young women. Others attempt to be representations of her figure and manner. I shall designate a model which is a representation, 'a first-order model;' and a model which is being represented, 'a second-order model.'[13] Returning to the illustration, the young woman is first a model of the ideal (first-order model), and is then a model for other young women (second-order model). First she represents, then she is represented.

Before bringing the distinction between first-order and second-order models to bear on the concept of theory, this concept must be disinvolved. A theory is a system of statements. The statements are conjectures that characterize objects, and so are called 'hypotheses.' When the hypotheses are evaluated and found to be adequate in terms of instances, they come to be called 'laws.' For example, Charles' conjecture or hypothesis which characterizes gases as follows:

> if the temperature of a gas increases, its volume will increase provided the pressure is constant, and the pressure will increase if the volume is constant

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[13] The terms 'first-order model' and 'second-order model' were suggested to me by W. T. Williams's paper, "The Problem of Communication in Biological Teaching," in Models and Analogues in Biology, op. cit. pp. 243-249.

has been evaluated and found to be adequate in terms of instances. It is called 'Charles' law.' The statements of a theory form a system, in so far as they are related so that from some as premises all the others follow. To return to our illustration, Charles' law is a statement within a system of statements known as 'the Kinetic Theory.' It is related to other statements such as

> a gas is composed of perfectly elastic properties moving at a high velocity.

These statements are premises from which Charles' law may be deduced.

The question as to the logical equivalence of 'theory' and 'model' is now answerable. All theories represent, because the statements of which they consist are characterizations of objects. They are models of objects. In the words of Wittgenstein:

> 4.01 Der Satz ist ein Bild der Wirklichkeit.
>
> Der Satz ist ein Modell der Wirklichkeit, so wie wir sie uns denken.[14]

Thus, 'theory' and 'model' are logically equivalent terms, provided 'model' is used in a first-order sense. I propose to use the adjective, 'representational,' to designate such a sense. 'Theory' and 'representational model' are synonymous terms.[15] 'Kinetic Theory' and 'Kinetic Representational Model' are synonyms.

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[14] Tractatus Logico-Philosophicus, London: Kegan Paul, Trench, Trubner & Co., 1922, p. 62.

[15] The relationship of logical equivalence or synonymity holds when the universe of discourse is science. Consider a universe of discourse which also includes first-order models, such as the young woman hired by the Powers' Agency. In this case, there would be first-order models that were not theories, yet all theories would be first-order models. The relationship would be that of class inclusion, where the class of theories is included in the class of first-order models ($T \subset M$, not $T \equiv M$).

The separation of models into first-order and second-order makes patent that models relating to retroduction or the devising of theory must be second-order. What is wanted is a point of view which can be represented. This process of representing results in the conjecture or theory. Furthermore, it is not the case that the conjecture or theory is logically equivalent to the point of view. The point of view is a model for the theory, and is not the same as the theory. It is represented in the theory.

Since the way of inquiring that would result in science without defect rests upon the devising of theory, retroduction, one only can deplore current usage of the term 'model' which does not take into account the second-order sense. One would have no major objection to the following remarks of Paul Meadows:

> The formulation of a model consists in conceptually marking off a perceptual complex. . . . Every model is a pattern of symbols, rules, and processes regarded as matching, in part or in totality, an existing perceptual complex. Each model stipulates, thus, some correspondence with reality, some relevance of items in the model to the reality, and some verifiability between model and reality.[16]

if he had modified the term, 'model,' with the term, 'representational.' Could it not be the case that 'physics' could be substituted for 'psychology' in the statement to follow of Broad, if physicists had not paid close attention to second-order models?

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[16] "Models, Systems and Science," in American Sociological Review, Vol. 22, No. 1, 1957, p. 4.

> Poor dear Psychology, of course, has never got far beyond the stage of medieval physics, except in its statistical developments, where the labours of the mathematicians have enabled it to spin out the correlation of trivialities into endless refinements.[17]

But physicists did; and among them was the outstanding nineteenth century theoretician, James Clerk Maxwell, who wrote concerning the use of a point of view to devise conjecture or theory. To elucidate this process and the relationship between the point of view and the theory, one essay of Maxwell's--"On Faraday's Lines of Force"--is of particular significance. First, he spoke of the relationship in terms of physical analogy:

> In order to obtain physical ideas without adopting a physical theory we must make ourselves familiar with the existence of physical analogies. By a physical analogy I mean that partial similarity between the laws of one science and those of another which makes each of them illustrate the other.[18]

Then he cited an example:

> The laws of the conduction of heat in uniform media appear at first sight among the most different in their physical relations from those relating to attractions. The quantities which enter into them are temperature, flow of heat, conductivity. The word force is foreign to the subject. Yet we find that the mathematical laws of the uniform motion of heat in homogeneous media are identical in form with those of attractions varying inversely as the square of the distance. We have only to substitute source of heat for centre of attraction, flow of heat

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[17] C. D. Broad, 'The "Nature" of a Continuant,' in Readings in Philosophical Analysis, ed. by Feigl and Sellars, New York: Appleton-Century-Crofts, Inc., 1949, p. 476. Since this is reprinted from Examination of McTaggart's Philosophy which was published in 1933, one wonders whether a statement made today by Broad would be so condemnatory. I should think not.

[18] The Scientific Papers of James Clerk Maxwell, ed. by W. D. Niven, Cambridge: The University Press, Vol. 1, 1890, p. 156.

> for accelerating effect of attraction at any point, and temperature for potential, and the solution of a problem in attractions is transformed into that of a problem in heat.
>
> This analogy between the formula of heat and attraction was, I believe, first pointed out by Professor William Thomson in the Camb. Math. Journal, Vol. III.[19]

Finally, he set forth the point of view which he used to devise his theory of electricity:

> It is by use of analogies of this kind that I have attempted to bring before the mind in a convenient and manageable form, those mathematical ideas which are necessary to the study of the phenomena of electricity. The methods are generally those suggested by the processes of reasoning which are found in the researches of Faraday . . . .[20]
>
> By referring everything to the purely geometrical idea of the motion of an imaginary fluid, I hope to attain generality and precision . . . . If the results of mere speculation which I have collected are found to be of use to experimental philosophers, in arranging and interpreting their results, they will have served their purpose . . . .[21]

Surely the passage of time since Maxwell's day has indicated that the generality and precision (theory) achieved through the idea of the motion of an imaginary fluid (point of view) did achieve arrangement and interpretation (integration) of electrical phenomena. The purpose was served.

Maxwell's discussion has clarified the nature of second-order models as they function in devising theory. The theory of mechanics furnished substance (concepts) and form or structure (ways of relating concepts) which were represented in another system of statements. So the theory of electricity emerged. The theory of mechanics was a devising model for the theory of electricity. Yet it was not the case that the theory of electricity was equivalent to a part or all of the theory of mechanics. There was partial similarity in substance (isosubstantism[22]) and in form (isomorphism), nevertheless the theory of electricity contained more than the substance and form from the theory of mechanics which were represented in it.[23] This may be generalized as follows: Theory characterizing other objects might furnish concepts or ways of relating concepts or both which can be utilized to characterize the objects we are pondering. If it does, it is a model for devising theory. One theory serves as a point of view from which to set forth another theory. A more precise rendering of this generalization might be:

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[19] Ibid., p. 157.

[20] Ibid.

[21] Ibid., p. 159.

A theory X is a devising model for a theory Y when

1. Y contains substance or form or both, Z, from X,
2. whatever is true of Z is true of Y, but
3. not whatever is true of Y is true of X.

Condition 1 permits representation of X in Y through substance alone, form alone, or both. Condition 2 insures either isosubstantism, isomorphism, or both. Condition 3 stipulates that Y cannot be equivalent to a part of or all of X.

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[22] I have coined this term, since there is none that I know of to indicate sameness in substance.

[23] Peirce used the term, 'retroduction,' to indicate that what is involved is a leading back. The theory or conjecture that emerges (conclusion) contains more than the theory or point of view from which it emerges (premises). The implication, then, can only hold from the conclusion to the premises.

Brodbeck treats of a special case, where the theory that emerges represents the form of the laws of the theory which is the devising model (Y contains Z where Z is the form of the laws from X), when she defines 'model.'

> Two theories whose laws have the same form are isomorphic or structurally similar to each other. If the laws of one theory have the same form as the laws of another theory, then one may be said to be a model for the other.[24]

Perhaps the tendency[25] to restrict the devising model to this special case is explained by the ease with which the operations involved can be specified. Consider once more Maxwell's example of a physical analogy.[26] Consider also what Brodbeck has to say.

> Suppose that one area, as indicated by a set of descriptive concepts, for which a relatively well-developed theory is at hand is said to be a model for another area, about which little is as yet known. The descriptive terms in the theory of the better-known area are put into one-to-one correspondence with those of the "new" area. By means of this one-to-one correspondence, the laws of one area are "translated" into laws of the other area. The concepts of the better-known theory are replaced in the laws by the concepts of the new area. This replacement results in a set of laws or hypotheses about the variables of the new area. If observation shows these hypotheses to be true, then the laws of both areas have the same form. The lawful connections are preserved and the two theories are completely isomorphic to each other. For example, suppose it is wondered whether rumors spread like diseases. That is, can the laws of epidemiology, about which quite a bit is known, be a model for a theory of rumor transmission? Or,

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[24] Op. cit., p. 379.

[25] Brodbeck overcomes this tendency when she speaks of models in physics. Ibid., pp. 398-401.

[26] See pages 21 and 22 of this report.

> to say the same thing differently, do the laws about rumors have the same form as the laws about diseases? The descriptive concepts in the laws of epidemiology are first of all replaced by letter variables. This reveals the form of the laws. The concepts referring to diseases are put into one-to-one correspondence with those referring to rumors. The letter variables in the epidemiological laws are replaced by the descriptive terms referring to rumors. This results in a set of hypotheses about rumors, which may or may not be confirmed. If, optimistically, these laws are confirmed, then the two theories have the same form.[27]

Another special case is the mathematical model. This case is assuming more and more importance in all realms.[28,29] However, there is a great deal of confusion both as to the nature and role of the mathematical model.

Confusion arises as to the nature of the mathematical model, because sometimes it is considered as a logical model and sometimes it is not.[30,31] I propose following Nagel's lead and not bothering to sort out mathematical models from logical ones. The category including both would be the formal model.[32] This makes sense for various reasons. It is no easy task to disentangle mathematics from logic. Some mathematics can be stated in terms of logic. Branches of modern mathematics can no longer be characterized as involving numerical considerations or space considerations. Yet both mathematics and logic are formal in nature. They both deal with nothing other than ways of relating. The statement from the sentential calculus (a logical calculus), '$p \supset q$,' tells us that two different statements, p and q, may be related so that it is not the case that both p is true and q is false. The mathematical statements, '$ab = 1$,' indicates that two quantities, a and b, vary inversely with each other. If we generalize the term 'theory' to mean formal theories as well as scientific ones,[33] then the generalization regarding the devising model[34] could hold for formal models. They would be a special case where Z is form.

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[27] Op. cit., p. 379.

[28] Mathematical Thinking in the Social Sciences, ed. by Paul F. Lazarsfeld, Illinois: The Free Press, 1954.

[29] J. G. Kemeny and J. L. Snell, Mathematical Models in the Social Sciences, Boston: Ginn and Co., 1961.

[30] Kenneth J. Arrow, "Mathematical Models in the Social Sciences," in The Policy Sciences, ed. by Lerner and Lasswell, Stanford: University Press, 1951, pp. 129-154.

[31] F. H. George, "Models and Theories in Social Psychology," in Symposium on Sociological Theory, op. cit., pp. 311-347.

[32] Ernest Nagel in The Structure of Science, New York: Harcourt, Brace and World, Inc., 1961, pp. 110-111 distinguishes formal and substantive analogies.

The role of the formal model is not clear, because often it is not recognized that the same formal model can be represented in many different scientific theories. Of course, it is obvious that all scientific theories must include necessarily a way or ways of relating concepts. The sentential calculus is an example of a formal model that is used in many contexts. As an illustration, $c \equiv. a \cdot b$ may be used to structure the following statements:

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[33] In the prior portion of the text, I have used 'theory' only in the sense of scientific theory.

[34] See page 23 of this report.

the level of interaction in a group is greater

the amount of friendliness in a group is greater

the amount of activity carried on by members in a group is greater

by allowing 'c,' 'a,' and 'b' to denote each in turn. Thus, the level of interaction in a group will be greater if and only if both the amount of friendliness and the amount of activity carried on are greater. Also $c \equiv . a \cdot b$ may be used to structure a firing relationship between two excitatory input fibers, a and b, and one output fiber, c.

Yet another confusion arises as to the nature of the formal model due to the proclivity of some to draw. The formal does not become the non-formal when it is schematized. It may, however, become less precise. The above firing relationship is pictured as:

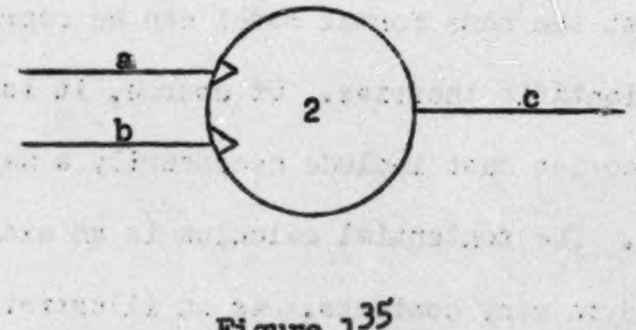

Figure 1[35]

A more familiar illustration might be the schematizing of class inclusion, $A \subset B$, in a Venn diagram:

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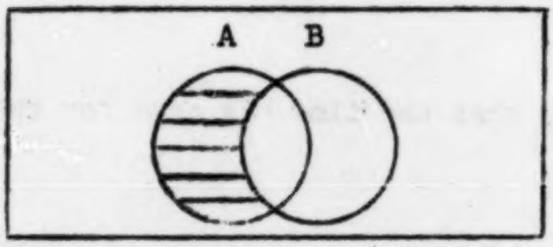
[35] F. H. George, op. cit., p. 316.



A final confusion relates to the role of the formal model. The formal model can devise, but it can also explicate and evaluate. To explicate is not to contribute theory, but is to clarify and complete theory. Such an explicatory formal model is exemplified by linear graph theory as Cartwright and Harary use it to clarify and complete Heider's theory.[36] To evaluate is not to contribute theory, but is to determine the objects falling within the range of the characterization or theory. It is a statistical argument, and

> . . . in no other branch of science is the word model as often and as consciously used as in statistics.[37]

One has but to mention the normal curve for illustrative purposes.

The context of models marked off by Hertz has been sorted about. Surely our child, retroduction, has been given meaning in terms of a devising model. What is necessary is the growth of the child, its use in the social sciences. Or as Feigl has put it

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[36] Dorwin Cartwright and Frank Harary, "Structural Balance: A Generalization of Heider's Theory," in The Psychological Review, Vol. 63, No. 5, 1956, pp. 277-293.

[37] Hans Freudenthal, "Models in Applied Probability," in The Concept and the Role of the Model in Mathematics and Natural and Social Sciences, ed. by Freudenthal, Holland: D. Reidel Publishing Co., 1961, p. 79.

> It would seem that the time has come for this sort of "Anschluss."[38]

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[38] Herbert Feigl, "Principles and Problems of Theory Construction in Psychology," in Current Trends in Psychological Theory, Wayne Dennis *et al.*, Pittsburgh: The University Press, 1951, p. 206.

THE WAY OF EDUCATIONAL THEORIZING THROUGH MODELS*

by

Elizabeth Steiner Maccia and George S. Maccia

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"Would you tell me, please, which way I ought to go from here?"

"That depends a good deal on where you want to get to," said the Cat.

> . . . the greatest and most difficult problem to which man can devote himself is the problem of education.[1]

Since we have devoted ourselves to such a problem, where we want to get to is a solution--"a true conception of the method of education."[2,3] The way, therefore, must provide for arrival at conceptions. Unless conceptions are forthcoming, how can they be evaluated as to their truth? Already the main outlines of such a way have been drawn. Retroduction, a way of inquiring which devises conceptions and so is a help to the mind in producing science without defect, has been noted.[4] Furthermore, retroduction has been given meaning in the context of models, points of view to be represented and so the source of conceptions.[5] What remains, therefore, is the delimitation of the way in relation to our given problem.

Even though the problem has been stated as that of education, more needs to be said if the way is to be clear. What is wanted is an adequate educational theory or true conceptions or characterizations of the phenomena falling within the domain of the educative process.

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[1] Immanuel Kant, Education, trans. by Annette Churton, Michigan: The University Press, 1960, p. 11.

[2] Ibid., p. 12.

[3] Notice that 'method' is being used in a more comprehensive sense than is usual. The reference is to the entire educative process and not to a way of teaching.

[4] See "Ways of Inquiring," the first paper in this section.

[5] See "Models and the Meaning of 'Retroduction'," the second paper in this section.

What phenomena fall within this domain? Surely what is involved are persons doing something within a certain kind of setting. Students, faculty, and other staff such as administrators are counted among the persons. The doing ranges from teaching-learning activities to budgetary ones. The certain kind of setting is a school within a community; that is to say, an interrelation of persons with persons and with physical objects.

Granted that what is sought is a theory to cover the entire domain of the educative process, nevertheless such theory is hard to come by. Consider that most educational theorizing which has been attempted is not of the comprehensive type. Dewey's theory[6] is almost singular in regard to scope. Rather educational theorizing falls within subcategories[7] depending upon the portion of the domain characterized. Theory of guidance[8] relates to persons; curriculum theory[9], theory of teaching (methods),[10] and learning theory[11] relates to the heart of the something done, the teaching-learning activities; and administrative theory[12] relates to the setting and some aspects of the something done.

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[6] See Democracy and Education and other works.

[7] Footnotes 8 through 12 cite recent educational theorizing in each of the subcategories.

[8] R. H. Mathewson, "School Guidance: a Four-dimensional Model," in Personnel and Guidance Journal, Vol. 39, 1961, pp. 645-649.

[9] M. Millar, "Some Roles of Subject Matter in Curriculum Inquiry," in School Review, Vol. 68, 1960, pp. 329-345.

[10] H. Robert Anderson, Ellis A. Hagstrom, and Wade M. Robinson, "Team Teaching in the Elementary School," in School Review, Vol. 68, 1960, pp. 71-84.

[11] W. Lawrence Downey, "Secondary Education: A Model for Improvement," in School Review, Vol. 68, 1960, pp. 251-265.

It would appear at first sight that the educational scientist is simply a social scientist[13] of a special kind. After all, his concern is with individual and group human behavior. What makes him a special kind of social scientist, of course, would be his interest in such behavior within a certain kind of setting, the school. But careful examination reveals something more. His endeavor usually involves commitment to a certain kind or kinds of behavior which are wanted. Rarely is it the case that the educational scientist is interested in simply characterizing the phenomena of the educative process. More often, he is interested in a characterization which includes an educational goal or goals. For example, when Guba turns to phenomena related to the curriculum, he becomes interested in a characterization which

> is . . . capable of directing the child toward responsible

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[12] Conrad Briner, "Unhinging the High School Principalship," in School Review, Vol. 68, 1960, pp. 318-328. The theorizing in this article is based upon the Getzels-Guba Administrative Theory.

[13] 'Social scientist' is taken here in a very broad sense. The title refers to all scientists who seek for true characterizations of human behavior. We prefer to use the term, 'hominological' rather than 'social.' 'Social' has the difficulty of ruling out the psychological which emphasizes the individual. The terms, 'psychological' and 'behavioral,' also are deficient. 'Psychological' has the difficulty of ruling out the social, and the added difficulty of emphasizing mind as an entity over and above the body ('psychological' comes in part from the Greek 'psychikos,' meaning soul or spiritual component). 'Behavioral' has the difficulty of bringing in concerns relating to animal behavior which properly belong in biology. 'Hominological' formed in part from the Latin, 'homin,' indicates the family Hominidae, and so the true concern which is man.

> behavior in the transactional sense here taken as appropriate in a democratic culture.[14]

An example from the popular genre would be the hue and cry directed at educationists to talk once more of the schools as places where "kids" are supposed to come to know. What it is to know is left vague and is argued about a great deal. Yet a characterization cannot be left vague, if it is to count as scientific. If goals are to be included in theory, then they must be given precision.

Now that where we want to get to has been clarified, the question of the way is before us. As already indicated, the essence of the answer resides in retroduction, or the utilization of a point of view as a model for devising educational theory. To say more about the way, a consideration of just such a devising undertaken for illustrative purposes should prove helpful.

Through a point of view from within the discipline of physiology, a theory of eye blinking, a conjecture or characterization of certain phenomena of the educative process, a theory of learning, was devised. Table I shows how the theory of eye blink is represented in the theory of learning, and thus is a devising model for it.

Although the illustrative theory was highly tentative in nature, a preliminary survey of the literature indicated a surprising degree of relevance and fruitfulness. By 'relevance' is meant connection of the theory

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[14] Egon G. Guba, Role, Personality, and Social Behavior, The Bureau of Educational Research and Service, The Ohio State University, 1958, p. 68.

MODEL	EDUCATIONAL THEORY
1. Either the eyes are or are not covered by lids.	1. Either the student is distracted ("mind" is closed) or attentive ("mind" is opened).
2. Blinking functions to protect the eye from contact and to rest the retina and the ocular muscles.	2. Distraction functions to protect from mental stress and to rest from mental effort.
3. Blinking may be either reflexive or non-reflexive.	3. Distraction may be either non-voluntary or voluntary.
4. Reflex blinking may be due either to corneal contact (touch competing with sight) or dazzle (sudden and intense light) or menace (movement of an object toward the eye).	4. Non-voluntary distraction may be due either to competing or sudden or intense or threatening stimuli.
5. Reflex blinking may be inhibited by a fixation-object or by drugs.	5. Non-voluntary distraction may be inhibited by attention cues or by drugs.
6. Non-reflexive blinking may occur if seeing is unwanted.	6. Voluntary distraction may occur if learning is unwanted.
7. There is a normal blinking rate statable in blinks per second.	7. There is a normal distraction rate statable in distractions per unit time.
8. There is a normal black-out index statable as 100 times the ratio of duration of blink to interblink.	8. There is a normal non-receptive index statable as 100 times the ratio of duration of distraction to attention.
9. A normal blinking rate or black-out index do not significantly affect vision.	9. A normal distraction rate or non-receptive index do not significantly affect learning.
10. Blinking rate increases with physiological excitation.	10. Distraction rate increases with mental excitation.
11. An excessive blinking rate can significantly impair vision.	11. An excessive distraction rate can significantly impair learning.
12. Malfunctioning in relation to blinking may occur due to inability to keep eyes open (blepharospasm) or due to fatigue of the eye (fibrillary twitchings).	12. Malfunctioning in relation to distraction may occur due to inability to be attentive (certain neuroses and psychoses) or due to mental fatigue.
13. Sleep is a sustained blink, and so inhibits most seeing.	13. "Mental sleep" (may or may not be physiological sleep) is a sustained distraction, and so inhibits most learning.
14. Normal sleep is recuperative for normal vision.	14. Normal "mental sleep" (relaxation) is recuperative for normal learning.
15. Normal sleep is preceded by a sleep ritual which usually includes voluntary closure of the eyelids.	15. Normal "mental sleep" is preceded by a relaxation ritual.

TABLE I

with other characterizations, and especially those which have checked out. By 'fruitfulness' is meant presentation, through the theory, of checkable characterizations beyond those we already have.

Turning first to relevance, Nichols[15] reports concerning words which were found to distract listening audiences. He writes as if such stimuli induce non-voluntary distraction; however, his list of emotion-laden words suggests that threatening stimuli are learned, and so, at least initially, must involve voluntary distraction. Stopol[16] employed failure stress as a distractor along with competing stimuli--bells, buzzers, and flashing lights; and his findings support the distinction between threatening and competing stimuli. Competing stimuli were employed or noted by the following investigators: McDowell[17], Freeburne[18], Kingsley and Garry[19], and Broadbent.[20] Nichols [21] and Broadbent[22] report studies in which intense stimuli were employed. Stopol noted in his study that

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[15] R. G. Nichols, "Ten Components of Effective Listening," in Education, Vol. 75, 1955, pp. 292-302.

[16] M. S. Stopol, "Consistency of Stress Tolerance," in Journal of Personality, Vol. 23, 1954, pp. 13-29.

[17] A. A. McDowell, "Comparisons of Distractibility in Irradiated and Non-irradiated Monkeys," in Journal of Genetic Psychology, Vol. 93, 1958, pp. 63-72.

[18] C. M. Freeburne, "Effect of Music Distraction Upon Reading Rate and Comprehension," in Journal of Educational Psychology, Vol. 43, 1952, pp. 101-109.

[19] H. L. Kingsley and R. Garry, The Nature and Conditions of Learning, New York: Prentice-Hall, 1957.

[20] D. E. Broadbent, Perception and Communication, New York: Pergamon Press, 1958.

[21] Op. cit.

[22] Op. cit.

> It therefore seems reasonable to believe that in the present study the introduction of a second stress stimulus increased the intensity of the stimulating state of affairs to a point resulting in greater loss of efficiency.[23]

Measures employing drugs and attention cues to inhibit distraction, as suggested by the theory, have been set forth by Daston[24] and Foulds[25]. Although no verification is set forth in his paper, Holmes[26] also emphasizes the importance of attention cues in relation to inhibition of distraction. Kingsley and Garry[27] speak of a form of distraction, daydreaming, which might be considered voluntary. The attempts to measure attention span, which are apparent in the early studies on attention, fit in with the possibility of a normal distraction rate and non-receptive index which is set forth in the theory. The experiments of Mayer and Van Haller[28,29] further suggest the feasibility of obtaining such a rate and index. Finally, the literature supports malfunctioning in relation to distraction arising from mental disturbance. The work of Daston[30] and of Foulds[31] can be cited.

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[23] Op. cit., p. 26.

[24] P. G. Daston, "Effects of Two Phenothiazine Drugs on Concentrative Attention Span of Chronic Schizophrenics," in Journal of Clinical Psychology, Vol. 15, 1959, pp. 106-109.

[25] G. A. Foulds, "Distraction and Affective Disturbance," in Journal of Clinical Psychology, Vol. 12, 1956, pp. 291-292.

[26] C. E. Holmes, "One Thing at a Time," in Journal of Business Education, Vol. 30, 1955, p. 353.

[27] Op. cit.

[28] K. E. Mayer and B. Van Haller, "Attention Spans of Children for Experimentally Designed Toys," in Journal of Genetic Psychology, Vol. 87, 1955, pp. 187-201.

[29] K. E. Mayer and B. Van Haller, "Concept of Attention Spans in Children," in Elementary School Journal, Vol. 54, 1954, pp. 464-466.

In regard to fruitfulness, the distinctions between competing, intense, sudden, and threatening stimuli suggested by the theory indicate an area of investigation into their effects and relative weight in developing distraction. In the research reviewed, the investigators assumed or ignored voluntary distraction. The theory hypothesizes that distraction may be induced voluntarily to shut out certain learnings. Attitudinal studies might shed some light on this aspect of distraction. Research on attention span appears to have overlooked the possibility of a normal rate of distraction and a normal non-receptive index which do not affect significantly an individual's learning. The measure of such a rate and index may have profound implications in regard to the teacher-student relationship and the media involved. The theory suggests that periods of relaxation are functionally related to learning, and this too has been suggested in the literature. Yet the theory opens up the possibility of a rigorous approach through rates and indices, rather than the usual rule-of-thumb approach. Undoubtedly more rigorous analysis would disclose many more possibilities; but the intent has been served, since fruitfulness has been shown.

What, then, does the illustrative devising tell us about the way? It is patent that at its very core the procedure is interdisciplinary. Within the discipline of education, what is wanted is adequate educational theory or true characterizations about the phenomena constituting the educative process. In a sense, what is sought is the making of education more of a discipline. The becoming of a discipline is becoming a body of knowledge, and a given body of knowledge is nothing other than adequate theory.[32] In the retroduction the discipline of physiology was used. That it is a discipline would not be contested, since it contains adequate theories about the functioning of living organisms. One of these theories, that of the eye blink, was used as a model to devise part of the discipline of education, a theory of learning. Surely betweenness of disciplines was involved.

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[30] Op. cit.

[31] Op. cit.

Two difficulties, common to all interdisciplinary work, immediately present themselves. Between what and what--what disciplines are to be interrelated--is the first. The second concerns who--in the light of contemporary specialization, the persons to carry out the work. In the context of the devising of educational theory through models, the first becomes what disciplines are to be marked off to explore for models, and the second becomes what qualifications are required of the theoreticians.

As a beginning point in the attempt to solve the first difficulty, a sorting out of the disciplines is necessary. Disciplines can be sorted into those forming part of the scientific endeavor and those which do not.

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[32] Let it be noted that (1) no discipline is ever completely made, since no theory is ever completely adequate; and (2) unification is only an ideal, for it is the case that no discipline has a comprehensive theory, but rather consists of theories covering different aspects of the phenomena within its domain. One has but to consider physics which numbers among the disciplines having the most right to the appellation, 'discipline.'

The former are of interest, for the concern is with such an endeavor in education. The aim is the development of scientific educational theory or adequate characterizations about the phenomena of the educative process. Disciplines forming part of the scientific endeavor are the empirical and the formal. The empirical disciplines, as their title indicates, are about experience or phenomena. Depending upon whether they are about non-human or human phenomena, they are either natural sciences or social sciences. Within the natural sciences, two subcategories are apparent in terms of the non-living and the living, the physical and biological. However, within the social sciences, the subcategories are not at all clear. This vagueness could be an indicator of the fact that the social sciences are in an earlier state of becoming disciplines than are the natural sciences. It is only after development of characterizations that the domain of phenomena, objects they refer to, can be subdivided. Nevertheless, psychology and sociology do belong within the social sciences, as does education.[33] The formal disciplines--logic and mathematics--are related to the scientific endeavor in so far as they provide ways of interrelating or structuring or forming characterizations about phenomena. Indeed, they are crucial, since the natural and social sciences only become so when, among other things, they are systematic, when their concepts are structured with precision.

This sorting about of the disciplines has marked off three areas to explore for devising models for educational theory: the natural sciences, the social sciences, and the formal disciplines. Can anything more be said that would indicate one area as worth exploring more than the others? The quest is for devising models, points of view from which scientific theory about education can arise. This means that an area containing more theory of a scientific nature has more to offer in regard to scientific form and substance. The scientific theory is the point of view, and through representation of it the sought-after new scientific theory arises. In the illustrative devising, not only did the scientific theory of eye blink furnish scientific form that could be represented, but it also furnished scientific substance. Not only did it suggest the relating of distraction to stimuli, but it suggested the kinds of stimuli: competing, sudden, intense, and threatening. Without a doubt, citation is unnecessary to substantiate the claim that the natural sciences have more to offer in this respect than do the social sciences. Who would contest the claim that the natural sciences contain more adequate theory than do the social sciences? The formal disciplines too suffer a limitation. They offer only form to be represented, when suggestions of a substantive kind also are required.

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[33] See page 32 of this report.

Although we are faced with the paradox that the sciences dealing with phenomena the most divergent from those of education appear to have the most possibility in the realm of devising models, yet the other two areas ought not to be ignored. Besides offering some possibility for devising models, the social sciences might give us representational models, i.e. ready-made theories which when explicated might characterize (represent) educational phenomena. This would not be surprising, since education is a social science. Its phenomena are those of individual and group human behavior. Besides offering some possibility for devising models, the formal disciplines might give us explicatory models, i.e. forms through which indefinite educational theory, which we have devised from another area or which we have taken over from another area, can be made definite.

Now that disciplines have been marked off for exploration, what of the second difficulty in regard to the nature of the explorers? It is patent that the key persons involved in developing educational theory should know education. Their field of specialization should be education.[34] They must know how far the discipline of education has come, so that it may be extended further. Yet it is this very extension and the way of doing it through other disciplines that requires more of them. Their competencies must extend into the disciplines being explored.[35] If the natural sciences are explored for devising models, then some competency is required therein. However, this is still not enough. Dorwin Cartwright, in introducing a work on a mathematical model for the social sciences, tells us why and what more is wanted:

> . . . but an individual social scientist can hardly aspire to master large areas of mathematics with the sheer hope that

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[34] In this project, all of the principal investigators, E. S. Maccia, G. S. Maccia, and R. Jewett, have at least one advanced degree in the discipline of education, and all are pursuing it as their specialty.

[35] The competencies of the principal investigators of this project extend beyond education into the formal disciplines and the natural and social sciences. Two of the principal investigators, E. S. Maccia and G. S. Maccia, have at least one degree in a discipline other than education.

> he may discover something which will be appropriate to his substantive problems.
>
> Cooperation between social scientists and mathematicians is required to solve this problem. Specialists in these fields must work together in a way that permits the social scientist to learn what ideas mathematics has to offer him, without the necessity of his becoming a mathematician. Once a promising lead has been discovered, the social scientist may need to acquire a working knowledge of the relevant branch of mathematics. But even then it will be profitable for the mathematician to continue working with the social scientist because new mathematical problems will usually be generated by the attempt to make new applications of mathematics.[36]

Stated in the context of educational theory development, the competencies of the educational scientist do not extend far enough. Consequently, a counterpart, from whatever area the educational scientist is exploring for models, must be available to work with him.[37]

The way of getting to adequate educational theory has been delimited in terms of its interdisciplinary qualities. Delimitation through educational disciplinary qualities still remains. This is required, for, even in the initial steps of the way of educational theorizing through models, the interdisciplinary phase in which the natural and social sciences and the formal disciplines are explored, an educational disciplinary phase must enter.

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[36] Frank Harary and Robert Z. Norman, Graph Theory as a Mathematical Model in Social Science, Ann Arbor: University of Michigan, Institute for Social Research, 1953, p. iv.

[37] The following counterparts from The Ohio State University Faculty whose competencies are in the natural sciences, the social sciences, and the formal disciplines respectively worked on this project with the principal investigators: Roland Fischer, Enrico L. Quarantelli, and Daniel J. Troy.

There is no completely[38] a priori way of knowing whether a given theory from another discipline can be used to solve our problem, adequate educational theorizing or characterization of the phenomena of the educative process. We cannot completely know beforehand whether a given theory from another discipline can be used to devise educational theory, to explicate educational theory, or used as educational theory. Stated differently, there is no completely a priori way of knowing whether a given theory from another discipline is a devising or explicatory model for educational theory, or even a representational model of educational phenomena. Only educational theorizing or cognizance of other educational theorizing or in some cases both will provide the way of knowing.

In the case of devising and explicatory models, they are found to be such through educational theorizing. Educational theorizing is nothing other than developing characterizations about educational phenomena through devising and explicating such characterizations. In the illustrative devising, a tentative theory of learning was set forth using the eye blink theory as a point of view. Through this setting forth it became known that the eye blink theory was a model for educational theory.

In regard to all the models, they are known in part to be such when the resulting theory is tentatively relevant[39] to education. Otherwise, the representational models would be models of something other than educational phenomena, and the devising and explicatory models would be models for sheer speculation rather than for educational theory. We must go to the literature on education, as was done in the case of the tentative learning theory, and tentatively determine whether the educational theory is coherent with other educational theory, particularly that which has proven adequate. Coherence can be noted in the power to summarize other educational theory. Indeed this is the kind of coherence one strives for in producing all science. Knowledge is a matter of integrating or bringing together. Scientists, however, strive for something more. They are interested in extending knowledge. They will not settle for theory that is relevant only. It must be fruitful.[40]

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[38] The term, 'completely,' is used to indicate that there are some a priori grounds. See pages 40 and 41 of this report.

[39] See pages 33 and 35 of this report.

> . . . it is now regarded by scientists as obvious that a good hypothesis may be expected to yield interesting new consequences.[41]

What we want are models for such good theory. To complete our knowing whether theory from other disciplines are models, the resulting theory must be tentatively appraised for fruitfulness. We must see whether there are new characterizations about educational phenomena, as was done in relation to the illustrative theory.

A final important aspect of the way, which has not been pointed out, should be noted. We have been speaking as if models are always found ready-made and never constructed. Consider once again Cartwright's advice that, although the lead has been discovered, the mathematician should stay on the job with the social scientist. He suggests that this advice be taken, because new mathematical problems may arise.[42] What he is telling us is that the formal theory as is may not be utilizable as a model. We may have to change it, and so construct what will be a model. Usually such construction will be called for.

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[40] See page 35 of this report.

[41] William Kneale, "Induction, Explanation, and Transcendent Hypotheses," in Readings in the Philosophy of Science, ed. by H. Feigl and M. Brodbeck, New York: Appleton-Century-Crofts, 1953, p. 361.

The way we go from here is clear in terms of where we want to get to. The methodology in terms of the problem is clear. The going remains. The first step in the task, the construction of educational theory models, now can be taken.

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[42] See page 42 of this report.

SECTION II

METATHEORETICAL BACKGROUND: MODELS IN THE ONGOING ENDEAVOR OF EDUCATIONAL THEORIZING

THE CONCEPTIONS OF MODEL IN EDUCATIONAL THEORIZING *

by Elizabeth Steiner Maccia

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*This paper first appeared as Occasional Paper 62-114, The Bureau of Educational Research and Service, The Ohio State University, 1962.

Here the Red Queen began again. "Can you answer useful questions?" she asked. "How is bread made?"

"I know that!" Alice cried eagerly. "You take some flour . . . "

"Where do you pick the flower?" the White Queen asked. "In a garden or in the hedges?"

"Well, it isn't picked at all," Alice explained, "It's ground . . . "

"How many acres of ground?" said the White Queen . . .

Introduction

While the term 'model' has been associated with educational theorizing at least since 1955,[1] it has been used in this connection with a variety of meanings. For the sake of a clear understanding of the role of the present venture of constructing educational theory models in that ongoing endeavor, what the conceptions of model are in educational theorizing should be presented. Conversation between the perverse Queens and perverse Alice should be made possible. Consequently, a survey has been undertaken of literature dealing with educational theory in which some conception of model was acknowledged,[2] and the present paper includes a report of that survey.[3]

This paper will consist of three parts. The first will set forth a system of categories for conceptions of model and the significance of each type of conception for educational theorizing. The second will set forth abstracts of the literature surveyed. In each abstract, the categories will be utilized to indicate the particular conception or conceptions of model. The third will generalize and evaluate the conceptions of model in educational theorizing. Evaluation will be in terms of significance for educational theorizing which was set forth in the first part.

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[1] Arthur P. Coladarci and Jacob W. Getzels, The Use of Theory in Educational Administration, Stanford: University Press, 1955.

[2] A conception of model could be used in educational theorizing, yet not be acknowledged.

[3] A. H. Jones, Research Associate, undertook the survey and abstracted the literature.

Categories and Their Significance[4]

According to what they are, models fall into two categories: object model and characterization model. Since there are objects and there are characterizations of them, the twofold distinction arises. If the characterization is about actually existing objects, then it is empirical. Our interest centers about empirical characterizations, for educational theorizing is an attempt to characterize actually existing objects falling within the domain of the educative process. In an empirical characterization, the statements not only express the nature of the objects, but also the way in which the objects are interrelated. The latter element or formal element of the empirical characterization if taken separately is a formal characterization. Our interest, therefore, includes formal characterizations.

An illustration should clarify these distinctions. Objects are being deliberately constructed and arranged--programmed computers[5]--to mimic phenomena of human behavior. Aspects of human problem solving have been so mimicked:

> Simulating human behavior in practical situations often turns out to be less difficult than might be expected. Ask a man to tell you how he goes about weighing salary, job

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[4] See the first section of this report in which these categories and their significance for educational theorizing are developed: "The Ways of Inquiring," "Models and the Meaning of 'Retroduction'," and "The Way of Educational Theorizing Through Models."

[5] Only a programmed computer is a functioning computer, and so could have use as a model.

> security, and the quality of his co-workers in choosing a job; he will tell you that they all depend on each other. But investigators at M.I.T.'s Lincoln Laboratory have found that in mimicking his mental process on a computer it is not necessary to worry about the way the three considerations affect each other. They devised a test that requires a man to choose one of two hypothetical jobs. They then had him estimate the importance he attached to the three criteria. They found that a computer, programmed to combine these separate estimates, came out rather close to the job choices made by the group tested. The supposed interdependence of the criteria could just be ignored.[6]

The characterization of this proposed computer or object can be given partly in terms of algebra. The interrelation of elements--input, output, and inner elements--called 'logical nets' can be stated as logical formulae. These formulae in turn can be expressed in the notation of matrix algebra which can be transposed into more abstract algebraic terms. To this formal characterization, a substantive dimension must be added to complete the characterization. The elements must be described in terms of hardware, i.e. designation of components of the circuits.[7] Thus, an empirical characterization would emerge.

Not all objects or characterizations are models. In order to be a model, an object or characterization must be put to certain uses. It must be used either to represent or to be represented. In the first use, the object or characterization is a model of whatever is being represented; and in the second use, the object or characterization is a model for whatever it is represented in. A model of would be a representational model, while a model for would be a non-representational model.

---

[6] John Pfeiffer, "Problems, Too Have Problems," in Fortune, Vol. LXIV, No. 4, 1961, p. 146.

[7] The interrelation can be stated diagrammatically by circuits. However, expression of interrelation through algebra is more precise.

In terms of the illustration cited above, the programmed computer and its characterization could be either representational or non-representational models. The programmed computer can be used to represent an aspect of problem-solving. If it is, then it is a representational model of the object type. The programmed computer can be used as a functioning to be represented in human behavior. If it is, then it is a non-representational model of the object type. The characterization can be used to represent the programmed computer. If it is, then it is a representational model of the characterization type. The characterization can be used as one to be represented in another characterization, that of problem-solving. If it is, then it is a non-representational model of the characterization type. 'Either . . . or' is not being used in the exclusive sense. For example, the characterization of the programmed computer could be used both as a representational and a non-representational model. First the characterization could be used to represent the programmed computer, then it could be used to be represented in a characterization of human problem-solving.[8]

The tree diagram on the following page summarizes the conceptions of models according to what they are and their use, and expresses the limitation of characterization based upon the interest in educational theorizing.

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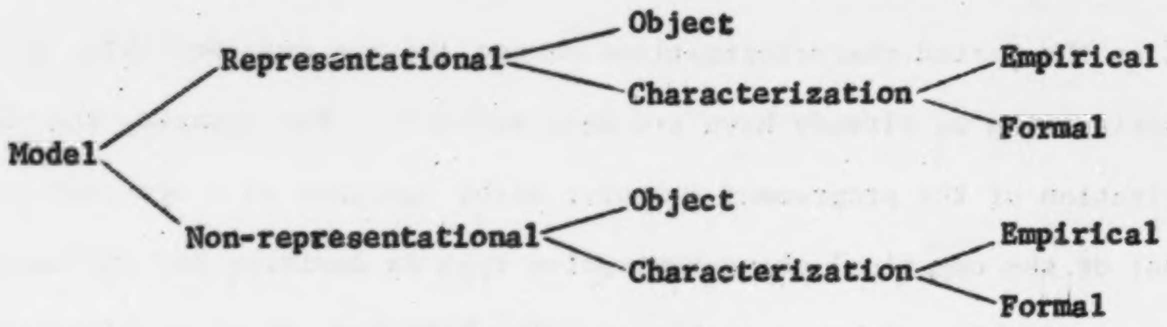
[8] In "Models and the Meaning of 'Retroduction'," this twofold usage was indicated by the terms, 'first-order' and 'second-order.' First an object or characterization represents, then it is represented.



Tree of Conceptions of Model

Each conception of model is not significant for educational theorizing. In order to determine significance for such an endeavor, it is necessary to point once again to the three main stages of scientific inquiry as they relate to educational theorizing and to the conceptions of model.

The three main stages of scientific inquiry are: retroduction through which characterizations are devised, deduction through which characterizations are explicated, and induction through which characterizations are evaluated. Educational theorizing is devising and explicating characterizations for objects falling within the educative domain. The stages of retroduction and deduction, thus, are stages in educational theorizing. Evaluating characterizations has a bearing upon devising and explicating them, in so far as characterizations which are found not to apply to the objects of interest are modified or even discarded. If they are discarded, other characterizations are devised and explicated. The stage of induction, thus, is a stage that leads to educational theorizing.

Non-representational models of the characterization type, whether they are empirical or solely formal, relate to retroduction and deduction.

It is through such models that characterizations are devised and explicated. Other characterizations furnish points of view which can be represented; and so the wanted characterizations emerge and are made definite, or characterizations we already have are made definite. For example, the characterization of the programmed computer might function as a non-representational model of the empirical characterization type in devising and explicating a characterization of human problem-solving behavior, or in explicating an already existing characterization of such behavior. In regard to the latter and not the former alternative, the probability is in favor of the formal component of the characterization of the programmed computer--the algebra--taken separately functioning as a non-representational model of the formal characterization type.

Non-representational models of the object type are not usable in retroduction and deduction. Characterizations, not objects, furnish points of view. This same reasoning rules out representational models of the object type; although all representational models, even when they are characterizations, have no role in devising and explicating characterizations. What is wanted is a model for not a model of.

Both representational models of the object type and the characterization type (empirical and formal) relate to evaluation. It is through the representational model of the object type that we can represent the objects of interest in terms of available objects. This permits having objects through which characterizations can be checked. The characterization that the interdependence of criteria was important in job choices could not be checked out easily, if at all, in the usual instances available--people making job choices. Through the use of an object, the programmed computer, representing the usual instances, the characterization was checked and found not to apply to instances. It is through representational models of the characterization type that we can represent the population of objects to which the instances being checked belong. This representation is in terms of the range of instances. Through such a representation, the degree of generalization from instances being checked to population can be ascertained. The result is evaluation of the characterization in terms of its application to the objects of interest. A familiar example of such a model would be the Gaussian distribution.

Conclusions as to the significance of the conceptions of model for educational theorizing now can be stated:

1. non-representational models of the characterization type are significant for doing the actual educational theorizing, i.e. devising and explicating educational theory; and
2. representational models of the object and the characterization types are significant for evaluating the results of educational theorizing, i.e. educational theory.

This discussion of the categories of the conceptions of model and their significance for educational theorizing can be summarized in the matrix on the following page which combines the categories set forth in the tree diagram[9] with categories of processes constituting or related to educational theorizing.

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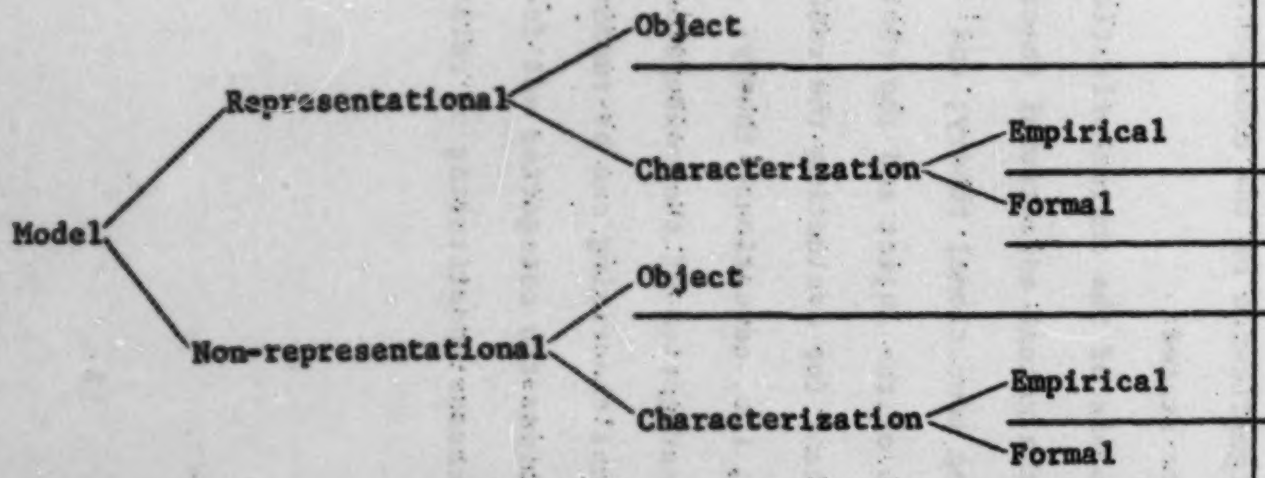
[9] See p. 50 of this report.


Model
Representational
Non-representational
Object
Characterization
Empirical
Formal
Object
Characterization
Empirical
Formal

	Devising	Explicating	Evaluating
Object	0	0	1
Empirical	0	0	1
Formal	0	0	1
Object	0	0	0
Empirical	1	1	0
Formal	1	1	0

'1' denotes significance for educational theorizing

'0' denotes no significance for educational theorizing

Matrix of Significance of Conceptions of Model for Educational Theorizing

Abstracts

Each abstract will consist of the following:

1. a statement of the purpose of the paper,
2. a summarization of the model or models, if any are presented, and
3. the conception or conceptions of model.

They will be presented in the alphabetical order of the authors' surnames.

1. Anderson, Robert H., Hagstrom, Ellis A., and Robinson, Wade M., "Team Teaching in an Elementary School," in School Review, 1960, Vol. 68, pp. 71-84.

Purpose of the Paper: The purpose is to report the development and operation of a team teaching program in Franklin Elementary School, Lexington, Massachusetts.

Model Presented: A program of personnel organization is presented, and may be summarized as follows:

> "The teaching team is a formally organized hierarchy whose basic unit is the teacher [T.] . . . ." (p. 76)
>
> "Above the position of teacher is that of senior teacher [S.T.]. Depending on the size of the team and the age of the pupils, the team may have one or more senior teachers. A small team may have none." (p. 76)
>
> "At the apex of the team hierarchy is the position of team leader [T.L.]." (p. 77)
>
> "The role of the principal under the teaching teams organization will probably become one of enhanced prestige and responsibility, somewhat akin to the present role of director of instruction." (p. 77)

The figure on the following page presents a schema of the organization. This figure also shows the inclusion of the following:

> "The part-time teacher (P.T.) is a fully trained teacher, usually experienced, who is unable to teach full time. A combination of two or three part-time teachers might fill a billet which would otherwise require one full-time teacher." (p. 83)
>
> "The intern (I.) is a trainee in a program of teacher education doing full-time supervised teaching in a school for one semester. The work of the intern is customarily directed by a senior teacher or team leader working with the training school supervisor." (p. 83)

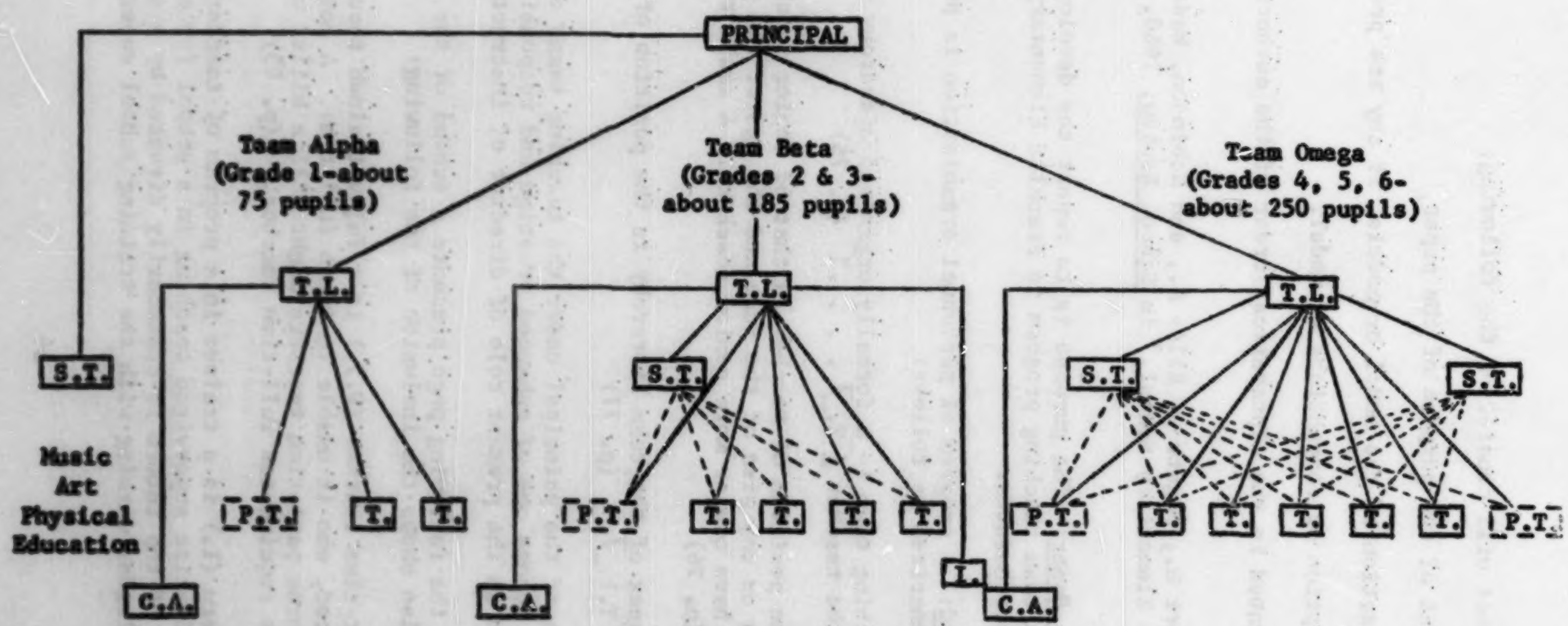

PRINCIPAL
Team Alpha (Grade 1-about 75 pupils)
Team Beta (Grades 2 & 3-about 185 pupils)
Team Omega (Grades 4, 5, 6-about 250 pupils)
T.L.
S.T.
P.T.
T.
I.
C.A.
Music
Art
Physical
Education

FIG. 2. Organization for team teaching in Franklin School for 1959-60. (p. 82)

"The clerical aide (C.A.) requires no professional preparation. This person will help with the routine, non-technical aspects of team operation: typing, rexographing, filing. It is possible that other sub-professional roles can be developed in this category, for example, technicians capable of producing instructional and demonstration materials." (p. 83)

Conception of Model: The program reported is twice called 'a model,' as follows:

"The project does not claim that all the components of its program or model are unique." (p. 81)

"What is unique about the Teaching Teams Project at Franklin School is the number and the particular combination of elements in its model." (p. 81)

Since the program is essentially an organization theory used to represent educative phenomena related to personnel, the conception of model is representational and of the empirical characterization type.

2. Ausubel, David P., "Forward," in Review of Educational Research: Growth, Development, and Learning, 1961, Vol. 31, No. 5, pp. 449-450.

Purpose of the Paper: The purpose is to introduce an issue of the Review of Educational Research devoted to surveying studies in growth, development, and learning.

Model Presented: The survey to which the issue is devoted is the model.

Conception of Model: Since Ausubel states: "By . . . providing a programmatic model for systematically ordering relationships . . . it is hoped that this issue can influence . . . research trends . . . ." (p. 450), the conception of model appears to be non-representational and of the empirical or formal characterization type. However, it could be the case that the survey presents the main outlines of characterizations which represent the phenomena of growth, development, and learning, and that Ausubel's intent is that more specific characterizations be devised in the progress of research from these. If so, the conception of model is representational and of the empirical characterization type.

3. Ausubel, David P. and Fitzgerald, Donald, "Meaningful Learning and Retention: Intrapersonal Cognitive Variables," in Review of Educational Research: Growth, Development, and Learning, 1961, Vol. 31, No. 5, pp. 500-510.

Purpose of the Paper: The purpose is to review research dealing with cognitive structure variables and cognitive style.

Model Presented: Bruner's theory that the memory of specific details of a discipline is a function of the degree to which the fundamental ideas or the structure of that discipline have been mastered is cited as a model.

Conception of Model: Since the theory is considered in relation to its use in representing educational phenomena related to learning, the conception of model is representational and of the empirical characterization type.

4. Campbell, Roald F. and Faber, Charles F., "Administrative Behavior: Theory and Research," in Review of Educational Research: Educational Organization, Administration, and Finance, 1961, Vol. 31, No. 4, pp. 353-367.

Purpose of the Paper: The purpose is to review recent literature dealing with the study of administrative behavior and of training programs in administration.

Model Presented: Organization theories as presented by March and Simon, and Hanlon's theory of administrative behavior are referred to and cited as models.

Conception of Model: Since the theories are considered in relation to their use in representing organization and administrative phenomena, the conception of model is representational and of the empirical characterization type.

5. Carroll, John B., "An Operational Model for Language Behavior," in Anthropological Linguistics, 1959, Vol. 1, No. 1, pp. 37-54.

Purpose of the Paper: The purpose is to present a model for language behavior; more specifically, by means of computer logic to represent such a model for the following aspects of language behavior: (1) original learning of language in the child, (2) learned verbal performance in a two- or multi-person communication situation, and (3) special verbal tasks demanded of individuals in certain psychological tests and experiments.

Model Presented: The model for language behavior is taken to be one which applies to all human behavior. It involves an individual with a central nervous system who is stimulated and who responds. Perception, discrimination, and reinforcement are taken for granted.

To the extent that "the contingencies /i.e., the particular conditions under which a response is reinforced/ are made uniform and tied in with a system of similar and coordinate responses, there can be said to exist a language" (p. 40). The three responses of particular interest are: (1) "a mand is any response which has been conditioned to come under the control of some specific deprivation state in such a way that when emitted it tends to elicit from an outside source (e.g., another person) the specific gratification for that deprivation" (p. 40), (2) "A tact . . . is a response which has been conditioned to come under the control of a specific external stimulus by virtue of having received some sort of generalized reinforcement" (p. 40), and (3) echoic (imitative) response.

Representation through computer logic of original learning of language in a child is shown in the display taken from the paper and presented on the following pages.

Conception of Model: Since the model is a theory which is used to represent language behavior, the main conception of model is representational and of the empirical characterization type. However, Carroll implies a non-representational model of the formal characterization type by representing the model by computer logic and by stating that "the demands of the programming for simulation by computer would force explicitness in assumptions" (p. 38). Furthermore, there is a sense of a representational model of the object type in that there would be an object to simulate the human verbal behavior. " . . . simulation by computer can help to narrow down the range of possible solutions, and it would enable one to generate large quantities of material which could be evaluated for vicisimilitudes." (p. 38)

6. Clymer, Theodore and Robinson, Helen M., "Reading," in Review of Educational Research: Language Arts and Fine Arts, 1961, Vol. 31, No. 2, pp. 130-144.

Purpose of the Paper: The purpose is to review research publications in reading for the period 1957-1960.

Model Presented: There is reference to a hypothesis by Smith and Carrigan, all reading disability is related to the balance of acetylcholine and cholinesterase at the junctions of the neurons, as a model.

Conception of Model: Since the hypothesis is used to represent educational phenomena related to reading, the conception of model is representational and of the empirical characterization type.

7. Coladarci, Arthur P. and Getzels, Jacob W., The Use of Theory in Educational Administration, Stanford: University Press, 1955.

Purpose of the Paper: The purpose is to show the value of and need for theory in educational administration, and to propose a theory of administration as a social process.

DISPLAY 1

BASIC PROGRAMS FOR ACQUISITION OF VERBAL RESPONSES IN EARLY LANGUAGE LEARNING

Assumed initial conditions of storage (the result of previous learning):

1. A repertoire of stimulus recognitions is available, i.e., responses to the routine PERCEIVE STIMULUS. This repertoire includes:
    - (a) Recognitions of various environmental stimuli (material objects) and their gratification values, if any (positive or negative).
    - (b) Recognitions of speech sounds of self and others, but the several sounds are not well discriminated.
2. A repertoire of speech motor habits is available, but the responses are not well shaped or discriminated. These speech motor habits are called by the routine BABBLE.

PROGRAM FOR SIMULATING THE ACQUISITION OF A MAND ("MANDACQ")

```
CALL BABBLE (= emits repertoire of speech motor habits; sequential dependencies will
    depend on relative degree of strength, perserveration, incidental reinforcement;
    activation of any given response remains momentarily in temporary storage)
        [This routine continues until broken by a STIMULUS emitted from an external
        source programmed to emit the stimulus only when a verbal response of
        approximately a specified phonetic shape occurs.
        So:]
STIMULUS
CALL PERCEIVE  (= subroutine
    which contains instructions
```

PROGRAM FOR SIMULATING THE ACQUISITION OF A TACT ("TACTACQ")

```
STIMULUS (X) (from external source--either fortuitous or programmed)
CALL PERCEIVE (see description under MANDACQ)
CALL REINFORCE (because there is no uniformity in the response present in temporary
    storage, the gratification value of the stimulus is irrelevant)
CALL BABBLE (the probability that this routine is called may be enhanced by the
    presence of a strong stimulus; the operation of the program is facilitated if,
    in addition, some particular response from the repertoire BABBLE is prompted,
    possible as an echoic response (see
```

PROGRAM FOR SIMULATING THE ACQUISITION OF AN ECHOIC RESPONSE ("ECHOACQ")

```
(This is a 'shaping' program for a single echoic response using the paradigm of TACTACQ.)

STIMULUS (V) (= a verbal response from an external source)
CALL PERCEIVE (initially the only familiarity characteristic of (V) is its being the
    familiar voice of an adult; with repetition of the program, it is also perceived
    as similar to a response previously made, in which case CALL SIMILAR occurs)
    (SIMILAR is a routine which places in temporary storage a distinctive similarity
    response.)
CALL REINFORCE (any
   referring stimulus to storage
   determining familiarity and
   gratification value of stimu-
   lus, returning appropriate
   signals to temporary storage)
CALL REINFORCE (= subroutine
   which notes gratification value
   of stimulus in terms of any
   current deprivation states;
   the strength or availability of
   any response remaining in
   temporary storage is enhanced
   proportionally to the gratifica-
   tion value of stimulus; in this
   case the motor responses just
   made under routine BABBLE
   are reinforced)
RETURN
```

(This loop may be repeated many times; depending upon the uniformity of the contingencies established by an external source, the specific verbal response acquires the power to control gratification for a specified deprivation state; 'shaping' may occur if the external source is programmed to reinforce only a progressively narrower range of responses. Further, this program is called upon as many times as needed for each of a finite number of verbal response types.)
(In ordinary language, we may say that the machine 'learns' that a given response 'means' the stimulus which gratifies it; the response itself is then called a MAND.)

```
   ECHOACQ program at right)
   from an adult speaker who
   'names' the stimulus.)
STIMULUS (Y) (This has been
   programmed in an external
   source such that it is emitted
   only when the machine makes
   a verbal response of a form
   which the external source
   considers appropriate to the
   stimulus:  this program will
   operate properly only if
   STIMULUS (Y) has a high re-
   ward value.)
CALL PERCEIVE
CALL REINFORCE (because
   STIMULUS (Y) has high re-
   ward value, it tends to rein-
   force the verbal response
   made in routine BABBLE)
RETURN (or leave program)
```

(This loop is repeated many times on different occasions; depending upon the programming of reinforcement a specific verbal response comes under the control of STIMULUS (X), i.e., STIMULUS (X) tends to be followed by CALL NAME OF X, a routine differentiated out of BABBLE.)

```
   perceptual response to the
   stimulus is reinforced if the
   adult's voice has positive grati-
   fication value, but this rein-
   forcement is mainly useful for
   enhancing the probability
   of calling the next subroutine)
CALL BABBLE (it is possible that
   certain responses from this
   repertoire would have been en-
   hanced by a feedback mecha-
   nism operating by virtue of
   the specific sounds heard; in
   any event, BABBLE continues
   (or terminates, in which case
   the program is left) until a
   response happens to be emitted
   which approximates the pho-
   netic shape of STIMULUS (V);
   there must then follow a STIM-
   ULUS (Y) which has been pro-
   grammed in an external source
   to be emitted only when the
   machine utters, within a rea-
   sonable period of time after
   (V), a verbal response of a
   form which the external source
   considers sufficiently close in
   phonetic shape to (V).  So:)
STIMULUS (Y) (must have high
   reward value)
CALL PERCEIVE
CALL REINFORCE (because
   STIMULUS (Y) has high re-
   ward value, it tends to rein-
   force the verbal response
   made in routine BABBLE)
RETURN((at option of external
   source, otherwise the pro-
   gram terminates)
```

Model Presented: A theory of administration as a social process, derived from Talcott Parsons, is presented and includes:

Definition of administration as a dyadic relationship, superordinate-subordinate

Analysis of relationship in terms of three dimensions, with specifications of alternatives within each:

- Authority:
  - Traditional
  - Charismatic
  - Rational
- Role:
  - Functionally diffuse
  - Functionally specific
- Affectivity:
  - Universalistic
  - Particularistic

Concept of effectiveness as measure of good administration

Proposition that effectiveness of administration is maximized when:

- Role expectations of superordinate and subordinate are congruous
- Authority is rational
- Roles are functionally specific
- Affectivity is predominantly universalistic

Conception of Model: Since the theory is taken to be a model and it is used to represent administrative phenomena including those of education, the conception of model is representational and of the empirical characterization type.

8. Creegan, Robert F., "A Modelistic Educational Theory," in School and Society, 1959, Vol. 87, pp. 511-512.

Purpose of the Paper: The purpose is to present a theory of education based upon the proposition that human learning takes place through the construction and modification of models of life and the world.

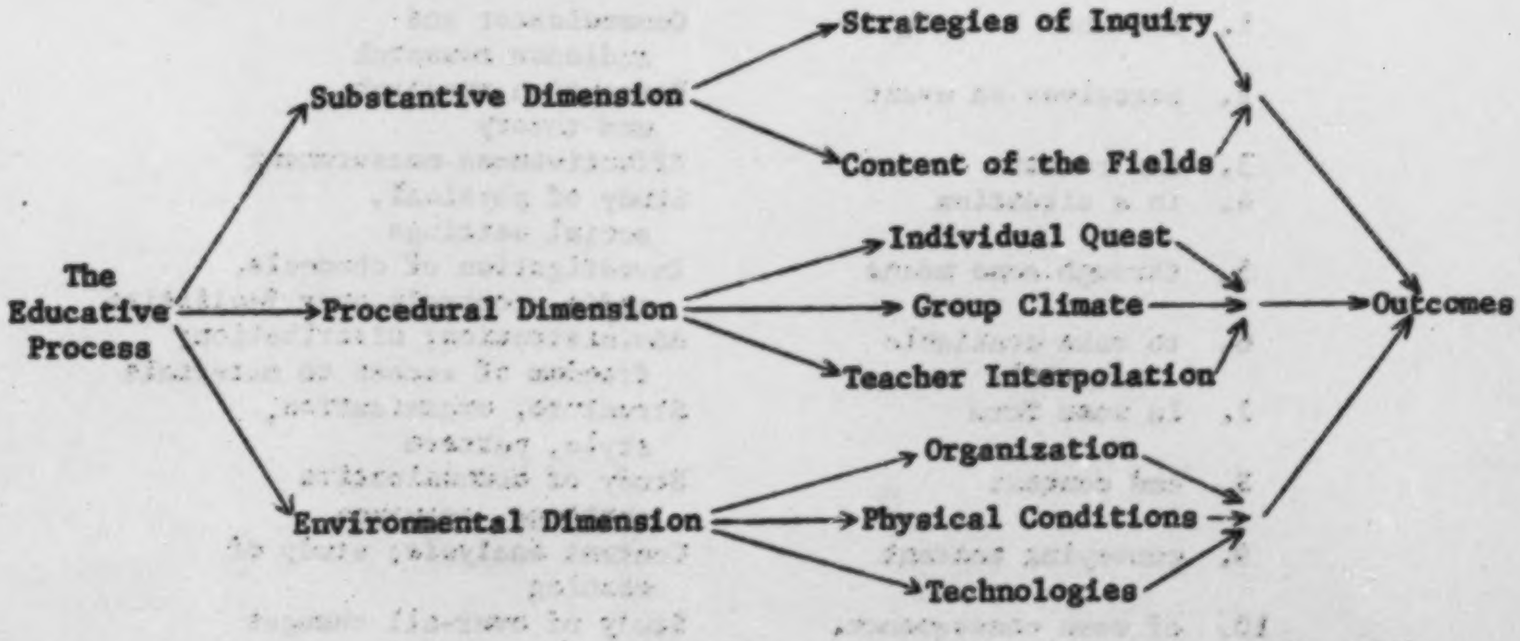
Model Presented: Listed as examples of models are super-patriotism, passive neutralism, Buddhism, Christianity, Hinduism, Judaism, New World education or Progressivism, Old World or formal education, Communism, and capitalism.

Conception of Model: Models are taken to be characterizations which represent life and the world; so the conception of model is representational and of the characterization type. However, all characterizations are not empirical or solely formal. Some represent objects which ought to exist, e.g. Christianity which characterizes what life ought to be, not what it actually is.

9. Downey, Lawrence W., "Secondary Education: A Model for Improvement," in School Review, 1960, Vol. 68, pp. 251-264.

Purpose of the Paper: The purpose is to show the value and need for theory in secondary education and to propose one.

Model Presented: A theory of secondary education is presented. Its main outlines are presented in the following diagram:


The Educative Process
Substantive Dimension
Procedural Dimension
Environmental Dimension
Strategies of Inquiry
Content of the Fields
Individual Quest
Group Climate
Teacher Interpolation
Organization
Physical Conditions
Technologies
Outcomes

(p. 259)

Conception of Model: The theory is used to represent the phenomena of the educative process, and so the conception of model is representational and of the empirical characterization type.

10. Gerbner, George, "Toward a General Model of Communication," *Audio-Visual Communication Review*, 1956, Vol. 4, No. 3, pp. 171-199.

Purpose of the Paper: The purpose is to present a general conception, which the author calls 'a model,' of communication for the purpose of stimulating the development of a technique and value-oriented theoretical structure.

Model Presented: A conception of communication involving ten basic aspects is set forth. The conception is presented in two forms; one is a sentence broken into ten parts and is called 'the verbal model,' while the other is presented in a series of diagrams and is called the 'graphic model.' About these Gerbner says:

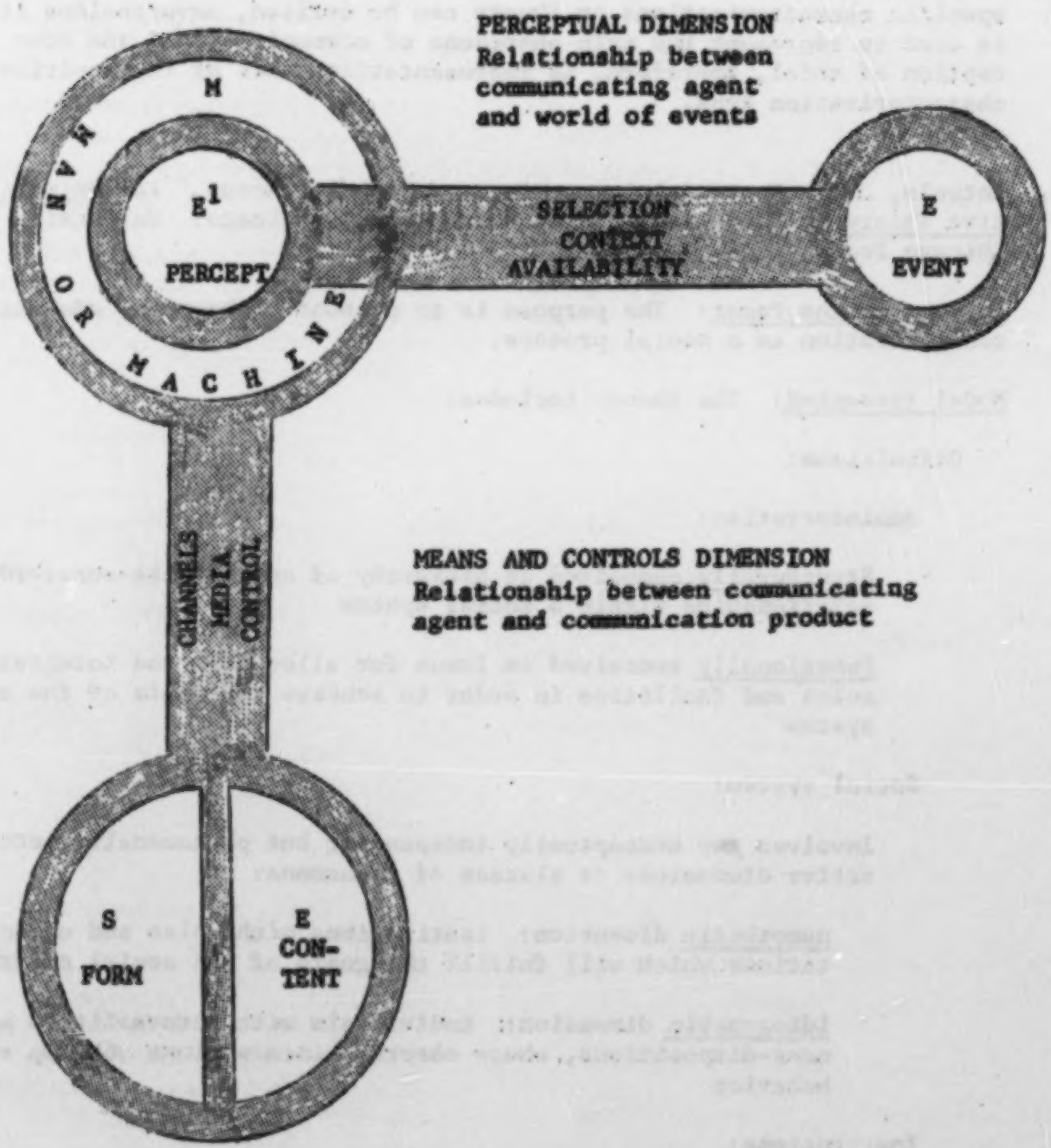
> . . . a graphic model can be cluttered up in the attempt to schematize concepts more clearly explained in words. So we shall use the two models jointly, and consider them two representations of the same basic model, each expressing certain things not easily described by the other. (p. 174)

The verbal model is used to classify areas of communication research as follows:

Verbal Model	Areas of Study
1. Someone	Communicator and audience research
2. perceives an event	Perception research and theory
3. and reacts	Effectiveness measurement
4. in a situation	Study of physical, social settings
5. through some means	Investigation of channels, media, controls over facilities
6. to make available materials	Administration; distribution; freedom of access to materials
7. in some form	Structure, organization, style, pattern
8. and context	Study of communicative settings, sequence
9. conveying content	Content analysis; study of meaning
10. of some consequence.	Study of over-all changes

(p. 173)

The graphic model is expressed in the diagram on the following page.


PERCEPTUAL DIMENSION
Relationship between
communicating agent
and world of events
M
E^1
PERCEPT
MAN OR MACHINE
SELECTION
CONTEXT
AVAILABILITY
E
EVENT
CHANNELS
MEDIA
CONTROL
MEANS AND CONTROLS DIMENSION
Relationship between communicating
agent and communication product
S
FORM
E
CON-
TENT

The basic generalized graphic model (p. 177)

/In this diagram, M represents (1) of the verbal model; E^1 - E represents (2), (6), (8); M - SE represents (3) and (5); S represents (7); E represents (9); and (4) and (10) are not represnted_7

Conception of Model: Even though the characterization which is called 'a model' is limited to that which is general and from which more specific characterizations or theory can be derived, nevertheless it is used to represent the main phenomena of communication. The conception of model, therefore, is representational and of the empirical characterization type.

11. Getzels, Jacob W., "Administration as a Social Process," in Administrative Theory in Education, ed. by A. W. Halpin, Chicago: University of Chicago Press, 1958, pp. 150-165.

Purpose of the Paper: The purpose is to present a theory of educational administration as a social process.

Model Presented: The theory includes:

Definitions:

Administration:

Structurally conceived as hierarchy of subordinate-superordinate relationships within a social system

Functionally conceived as locus for allocating and integrating roles and facilities in order to achieve the goals of the social system

Social system:

Involves two conceptually independent but phenomenally interactive dimensions or classes of phenomena:

nomothetic dimension: institutions with roles and expectations which will fulfill the goals of the social system

idiographic dimension: individuals with personalities and need-dispositions, whose observed interactions make up social behavior

Institutions:

Agencies established to carry out routinized imperative functions of social systems

Roles:

Most important analytic subunits of institution

Dynamic aspects of positions, offices and statuses within institutions, defining behavior of role incumbents or actors

Defined in terms of role expectations--normative obligations and responsibilities

Within an institution are interdependent or complementary; each deriving its meaning from other related roles in the same institution

Those prescribed within the existential social system are perceived by their role incumbents, and by other persons who interact with those incumbents, each in terms of his own needs, dispositions, and goals (When such private perceptions of two or more individuals are congruent, they may be said to understand each other; when the perceptions are incongruent, to misunderstand each other.)

Individuals:

Specific persons occupying roles, and behaving--fulfilling or failing to fulfill role expectations--in specific ways

Personality:

The dynamic organization within the individual of those need-dispositions that govern his unique reactions to the environment

Need-dispositions:

Individual tendencies to orient and act with respect to objects in certain manners and to expect certain consequences from these actions

The following diagrammatic presentation of relationships:

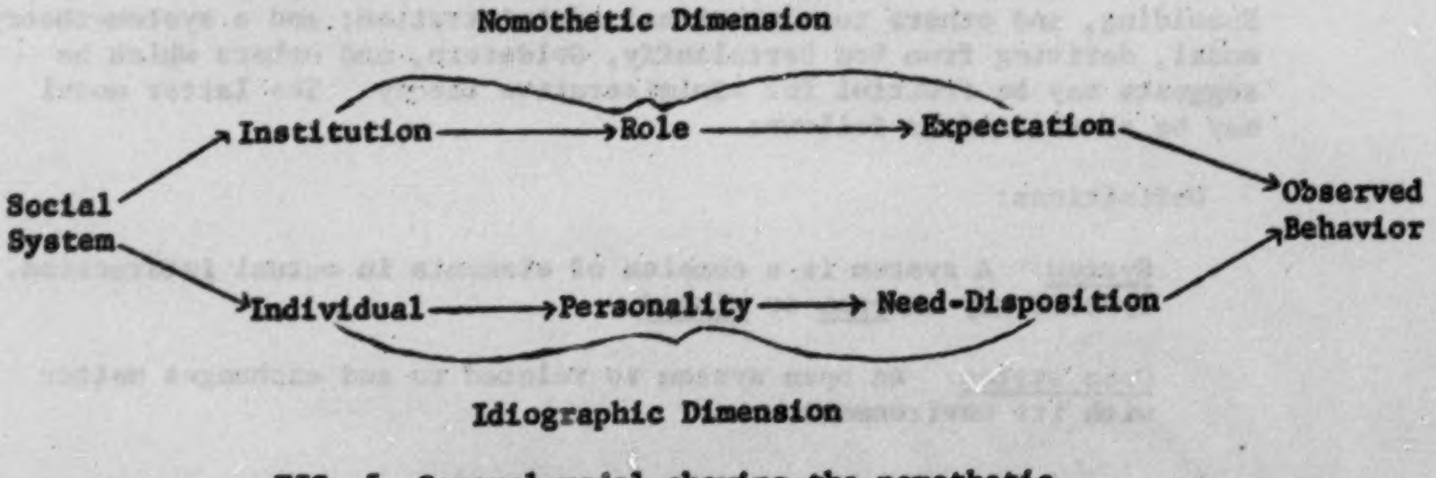

Nomothetic Dimension
Institution
Role
Expectation
Social System
Observed Behavior
Individual
Personality
Need-Disposition
Idiographic Dimension

FIG. 5. General model showing the nomothetic and idiographic dimensions of social behavior. (p. 156)

In each dimension, each term is the analytic unit for the term preceding it. A given act is conceived as deriving simultaneously from both dimensions.

Conception of Model: As in the Coladarci-Getzels paper (7), the conception of model is representational and of the empirical characterization type, since the model is a theory which is used to represent phenomena of administration.

12. Gregg, Russell T., "Administration," in Encyclopedia of Educational Research, ed. by Chester Harris, New York: MacMillan, 1960 (3rd edition), pp. 19-24.

Purpose of the Paper: The purpose is to present a general survey of research in educational administration.

Model Presented: Reference is made to Halpin's paradigm.[10]

Conception of Model: The term 'model' is used only in reference to the paradigm outlined by Halpin in Administrative Behavior in Education. Hence, the term would seem to mean here what Halpin meant by it--a representational empirical characterization.

13. Griffiths, Daniel E., "Some Assumptions Underlying the Use of Models in Research," in Research in Educational Administration, ed. by Stephen P. Hencley, Cooperative Research Project #2, 1962, pp. 43-59.

Purpose of the Paper The purpose is to discuss the nature of models and the assumptions underlying their use, and to propose a model for theory in educational administration.

Models Presented: Griffiths discusses two models: a machine model deriving from Locke, Montesquieu, Newton, and others, applied by Frederick W. Taylor to organization theory and by Strayer, Cubberley, Spaulding, and others to educational administration; and a system-theory model, deriving from Von Bertalanffy, Goldstein, and others which he suggests may be fruitful for administrative theory. The latter model may be summarized as follows:

Definitions:

System: A system is a complex of elements in mutual interaction. Systems may be open or closed.

Open system: An open system is related to and exchanges matter with its environment.

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[10] See abstract 16.

Closed systems: A closed system is not related to and does not exchange matter with its environment. A closed system tends toward entropy.

Properties of organismic, open systems:

Open systems exchange energy and information with their environment. They have inputs and outputs.

Open systems tend to maintain themselves in steady states.

Open systems are self-regulating.

Open systems display equifinality.

Open systems maintain their steady states, in part, through the dynamic interplay of subsystems operating as functional processes.

Open systems can maintain their steady states through feedback processes.

Open systems display progressive segregation.

The question whether the administrative performance of school principals is isomorphic to systems theory is raised. A study of school principals is cited as indicating that the properties ascribed to open systems do seem to characterize administrative performance.

The system-theory model is used to develop propositions about administration:

"The steady state of an administrative performance system is maintained by a decision process in which satisfactory alternatives are selected rather than optimal alternatives." (p. 57)

"Administrative systems respond to continuously increasing stress first by a lag in response, and finally by a catastrophic collapse of the system." (p. 58)

Conception of Model: The system-theory model is a characterization which is used to devise another characterization, administrative theory; hence, the conception of model is non-representational and of the empirical characterization type.

14. Griffiths, Daniel E., "Toward a Theory of Administrative Behavior," in Administrative Behavior in Education, ed. by Roald F. Campbell and Russell T. Gregg, New York: Harper, 1957, pp. 354-390.

Purpose of the Paper The purpose is to investigate the nature of theory, the manner in which it is constructed, and its use; to review some attempts to construct a theory of administrative behavior; and to propose a procedure for the construction of administrative theory, using the paradigm presented by Halpin.[11]

Model Presented: Halpin's paradigm is cited. In addition, Griffiths designates as models an earlier formulation of his own which he calls the tridimensional concept, and Herbert Simon's mathematical formulation of Homan's theory of interaction within a group.

The following table taken from Griffiths' paper summarizes his concept:

TABLE 1

THE TRIDIMENSIONAL CONCEPT OF EDUCATIONAL ADMINISTRATION
A FRAME OF REFERENCE

The Job	The Man	The Social Setting
CONTENT	CAPACITY	CONTENT
1. maintaining effective interrelationships with the community	1. physical	1. physical, technological, human resources
2. improving educational opportunity	2. intellectual	2. relational systems
3. obtaining and developing personnel	3. emotional	3. network of organization
4. providing and maintaining funds and facilities	4. spiritual	4. patterns: thought, belief, values
PROCESS	BEHAVIOR	PROCESS
1. sensing problems	1. sensing problems	1. continuity and stability
2. relating the problem	2. making inferences	2. new and different
3. making decisions	3. relating to people	3. stresses and strains
4. implementing	4. predicting and deciding	4. resolution and readjustment
	5. implementing	
SEQUENCE	SEQUENCE	SEQUENCE
1. past	1. past	1. deeply rooted traditions
2. present	2. present	2. recent past
3. future	3. future	3. present and near future
		4. long-range future

(p. 369)

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[11] See abstract 16.

The following quotation states the interrelation of man to job to social setting.

> The Man brings to the Job certain capacities of body, mind, emotions, and spirit. He has beliefs, values, expectations, behavior patterns, energy reserves, and skills. While the Job shapes him, he is also shaping the Job. The Social Setting encompasses the pressures and compulsions of society. These not only establish and set limits for the Job, but also influence the thinking of the Man and set values by which he adjusts himself and is judged. (pp. 368-369)

Griffiths summarizes Simon's formulation as follows:

Definition of variables (each variable stated as function of time, t):

$T(t)$ = intensity of interaction (communication)

$I(t)$ = amount of friendliness (group identification) among members

$W(t)$ = total amount of activity of a member of a group

$F(t)$ = activity of a group required for survival

Postulates:

If the scheme of activities is changed, the scheme of interaction will, in general, change also, and vice versa.

Persons who interact frequently with one another tend to like one another.

If the interactions between the members of a group are frequent in the external system, sentiments of liking will grow up between them, and these sentiments will lead in turn to further interaction over and above the interactions of the external system.

Persons who feel sentiments of liking for one another will express those sentiments in activities over and above the activities of the external system, and these activities may further strengthen the sentiments of liking.

The more frequently persons interact with one another the more alike in some respects both their activities and their sentiments tend to become.

In terms of those postulates and the symbols, the following equations are formulated:

$$T = a_1 I + a_2 W$$

This means that interaction is produced by friendliness and/or group activity. If both are present there will be more interaction than if only one is present.

$$\frac{dI}{dt} = b(T - \beta I)$$

This means that friendliness will tend to increase if the amount of interaction is disproportionately large in relation to existing friendliness, or will tend to decrease if the amount of interaction is disproportionately small in relation to existing friendliness. When interaction is equal to friendliness the right-hand side of the equation would be zero, the factors being in adjustment, and so there would be no tendency toward change.

Conception of Model: Griffiths' description of Simon's formulation suggests that he means by 'model' the characterization or theory stated in mathematical form which is used to represent group behavior. The conception of model, thus, is representational and of the empirical characterization type. On the other hand, he explicitly asserts that his tridimensional concept, like Halpin's paradigm, is not a theory but a framework for discussing administrative behavior. However, the conception of model is the same, if one realizes that by 'framework' is actually meant the broad outlines of a theory.

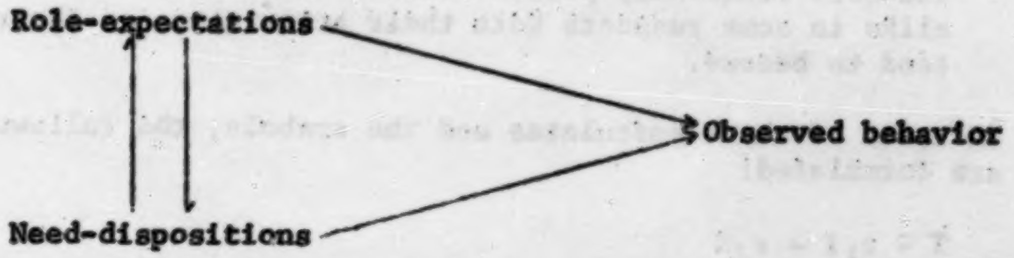
15. Guba, Egon G., Role, Personality, and Social Behavior, Bureau of Educational Research and Service, The Ohio State University, 1958.

Purpose of the Paper: The purpose is to present a theory of social behavior and to examine it in terms of its consequences in various social areas.

Model Presented: The model is basically the theory presented by Getzels in the article reviewed above. Guba's version differs from Getzels' chiefly in the areas into which the theory is extended.

An example is the following analysis of the educative process:

Diagram of relevant portion of theory:



Definition of educative process:

Guiding the pupil in integrating the demands of the school as a social institution with his own individual demands in ways at once institutionally productive and individually fulfilling

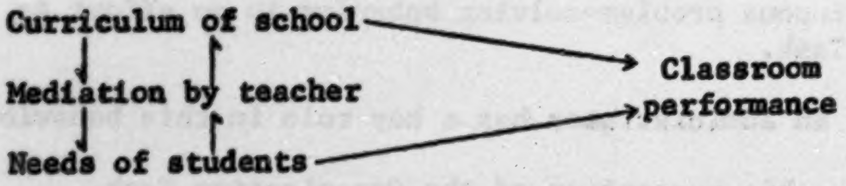
Use of the model to determine three problematic factors in the educative process:

Curriculum: the expectations set by the school for the student

Self-consistency: the nature and operation of the needs-systems students bring to the classroom

Method: the manner in which the teacher mediates between the curriculum and the needs-systems of the pupils to bring about acceptable classroom performance

The relation between these factors may be diagrammed thus:



Conception of Model: Since the model is the theory used to represent phenomena of social behavior including that of education, the conception of model is representational and of the empirical characterization type.

16. Halpin, Andrew W., "A Paradigm for Research on Administrative Behavior," in Administrative Behavior in Education, ed. by Roald F. Campbell and Russell T. Gregg, New York: Harper, 1957, pp. 155-199.

Purpose of the Paper: The purpose is to present a framework which will serve as "the basis for a systematic classification and critique of existent and ongoing research on administrator behavior, and . . . suggest fruitful lines of inquiry for new research" (p. 155).

Model Presented: The model presented is predicated upon the following assumptions:

Methodological:

It is desirable to confine inquiry to concepts having definable referents in behavior or in products of behavior.

It is important to discriminate between descriptions of behavior and evaluations of behavior.

Strategic:

That apart from educational administration, hospital administration, etc., administration qua administration is a domain worthy of study.

That it is more profitable to focus upon behavior of administrators than upon administration or administrative behavior.

Concerning educational administration:

That public school organization has a purpose statable operationally in terms of desirable behaviors or products of behavior. This is the Organization Task.

That individuals constituting an organization are engaged in continuous problem-solving behavior in an effort to accomplish the Task.

That an administrator has a key role in this behavior, especially in

a. his perception of the Organization Task,
b. his behavior as a Decision Maker,
c. his behavior as a Group Leader.

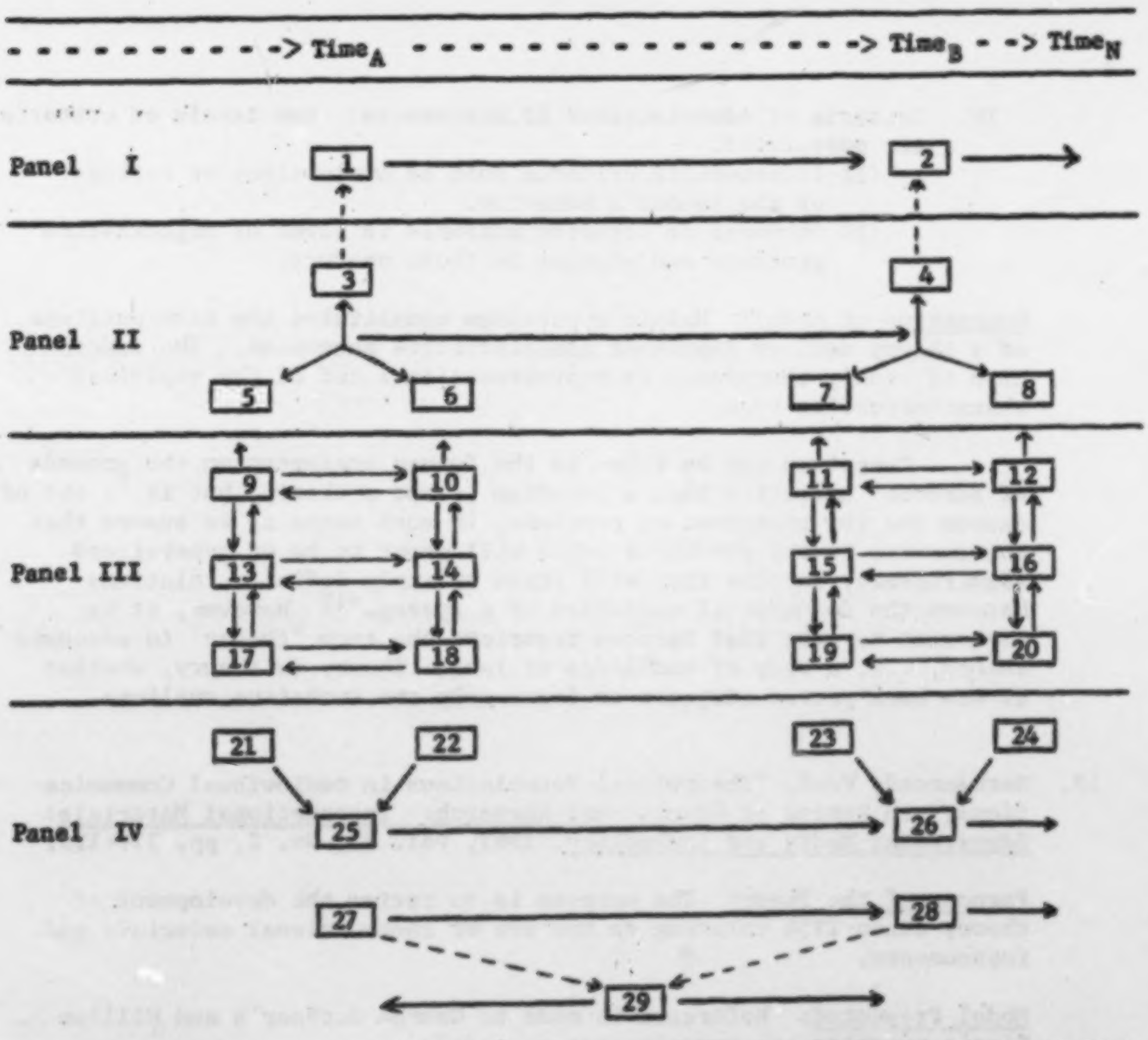
That administration is a human activity involving four components: the Task, the Formal Organization, the Work Group or Groups, and the Leader or Leaders.

The model is presented in the paradigm on the following page which is set forth in terms of four panels:

I. The Organizational Task: defined in terms of desirable behavior or behavior products.

II. Administrative Behavior: the behavior of the officially designated leader in his administrative role.

III. Variables Associated with Administrative Behavior: these include behavior on the part of group members other than the leader, products of the behavior of group members, specified conditions under which the administrator and other group members are required to operate, patterns of administrative organization, and community factors that bear upon the formal organization. These variables are to be reported objectively and measured reliably.


- - - - - - - - - - -> Time$_A$ - - - - - - - - - - - - - - - - - -> Time$_B$ - - -> Time$_N$
Panel I
1
2
Panel II
3
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Panel III
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Panel IV
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1. The Task$_A$
2. The Task$_B$
3. Administrator's Perception of Organization's Task
4. Administrator's Perception of Organization's Task
5. Behavior as a Decision Maker
6. Behavior as a Group Leader
7. Behavior as a Decision Maker
8. Behavior as a Group Leader
9. Administrator Variables
10. Administrator Variables
11. Administrator Variables
12. Administrator Variables
13. Intraorganization Variables
14. Intraorganization Variables
15. Intraorganization Variables
16. Intraorganization Variables
17. Extraorganization Variables
18. Extraorganization Variables
19. Extraorganization Variables
20. Extraorganization Variables
21. Evaluation as a Decision Maker$_A$
22. Evaluation as a Group Leader$_A$
23. Evaluation as a Decision Maker$_B$
24. Evaluation as a Group Leader$_B$
25. Organization Maintenance
26. Organization Maintenance
27. Organization Achievement$_A$
28. Organization Achievement$_B$
29. Change (Box 28 - Box 27)

Modified from Figure 6, Paradigm for Research on Administrator Behavior, p. 190.

IV. Criteria of Administrator Effectiveness: two levels of criteria are postulated.
   (1) Intermediate criteria such as evaluations or ratings of the leader's behavior.
   (2) Outcomes of behavior measured in terms of organization products and changes in these products.

Conception of Model: Halpin's paradigm constitutes the main outlines of a theory used to represent administrative phenomena. The conception of model, therefore, is representational and of the empirical characterization type.

Exception may be taken to the former statement on the grounds of Parsons' assertion that a paradigm is not a theory, but is "a set of canons for the statement of problems, in such terms as to ensure that the answers to the questions asked will prove to be of generalized significance, because they will state or imply definite relations between the fundamental variables of a system."[12] However, it is important to note that Parsons restricts the term 'theory' to adequate theory, i.e. a body of knowledge of laws. Theory is theory, whether it has been proven adequate or forms only the tentative outlines.

17. Harcleroad, Fred, "Theoretical Formulations in Audiovisual Communications," in *Review of Educational Research: Instructional Materials: Educational Media and Technology*, 1962, Vol. 32, No. 2, pp. 119-126.

Purpose of the Paper: The purpose is to review the development of theory since 1956 relating to the use of instructional materials and instruments.

Model Presented: Reference is made to George Gerbner's and William A. King's theories of communication as models.

Conception of Model: A "model of the communication process" (pp. 120, 123) indicates the conception of model as representational and of the empirical characterization type.

18. Jackson, Jay, *Normative Structure in Educational Systems*, Paper read at Washington University Conference on the Classroom as a Social System, January 15-17, 1962, St. Louis, Missouri.

Purpose of the Paper: The purpose is to propose a theory of normative structure as the essential regulating core of a social system, and to suggest that this theory is relevant to educational social systems.

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[12] Talcott Parsons, *The Social System*, Illinois: The Free Press, 1951, pp. 485-486.

Model Presented: The normative situtation is analyzed to include the possibility of a given type of behavior, which type could be exhibited in varying degrees, and a potential social return for that behavior, which can also be exhibited in varying degrees of approval or disapproval. This analysis is show in the diagram on the following page.

Conception of Model: The theory which is used to represent phenomena of a social system, including an educational social system, is called 'a model.' Hence, the conception of model is representational and of the empirical characterization type.

19. Johns, Roe L. and McLure, William P., "Economics and Finance of Education," in Review of Educational Research: Educational Organization, Administration, and Finance, 1961, Vol. 31, No. 4, pp. 417-427.

Purpose of the Paper: The purpose is to review recent literature relating to the economics of education.

Model Presented: Economic theories, Strayer's and Haig's proposals in 1923 of equalized foundation programs of support, and a theory proposed by Mort and Furno to explain the forces that shape school quality are referred to and called 'models.'

Conception of Model: Since models are taken to be theories which are used to represent economic phenomena, the conception of model is representational and of the empirical characterization type.

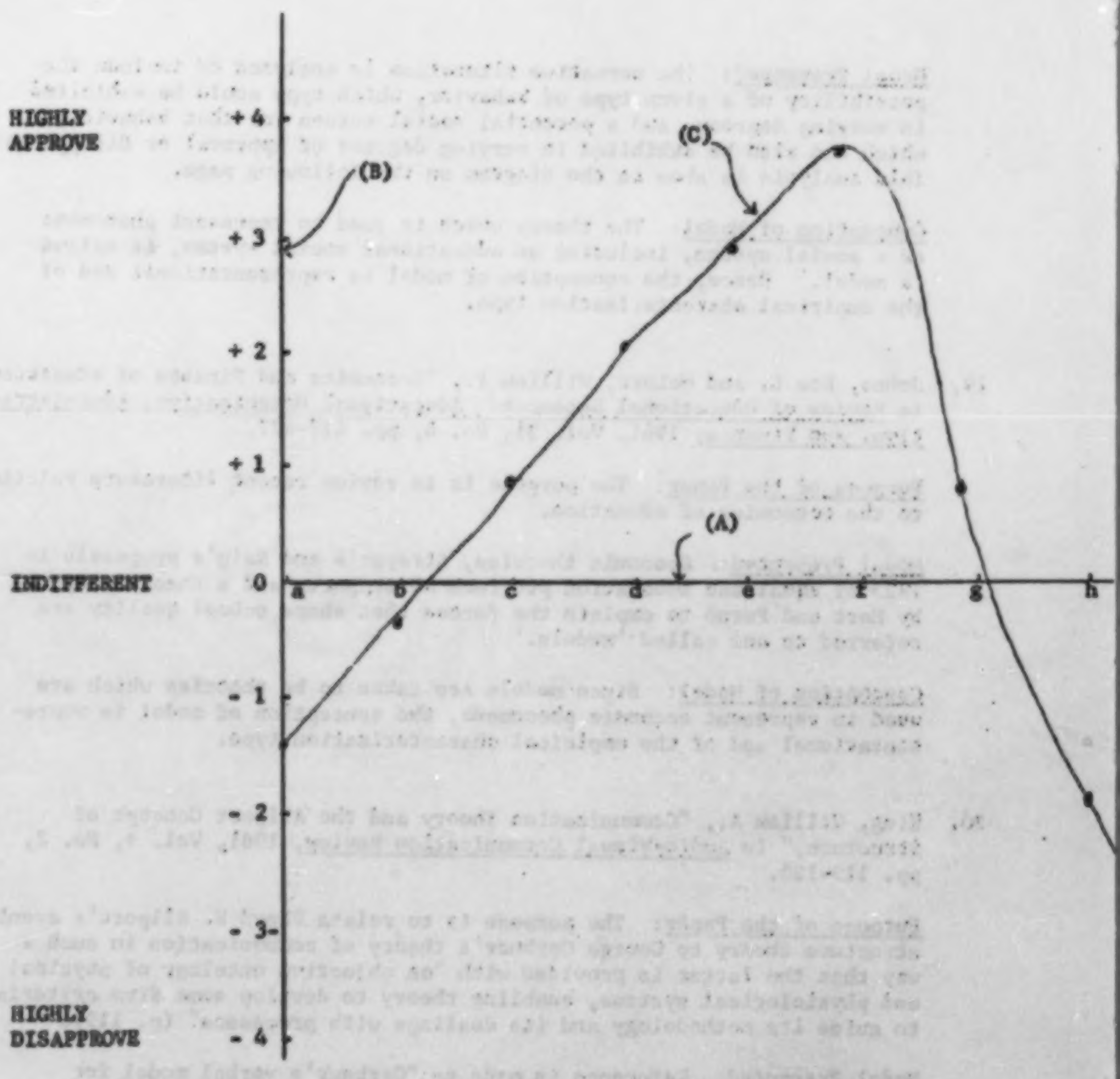
20. King, William A., "Communication Theory and the Allport Concept of Structure," in Audio-Visual Communication Review, 1961, Vol. 9, No. 2, pp. 119-128.

Purpose of the Paper: The purpose is to relate Floyd H. Allport's event-structure theory to George Gerbner's theory of communication in such a way that the latter is provided with "an objective ontology of physical and physiological systems, enabling theory to develop some firm criteria to guide its methodology and its dealings with processes" (p. 119).

Model Presented: Reference is made to "Gerbner's verbal model for communication" (p. 119). Key concepts and postulates from Allport's event-structure theory are set forth, and then Gerbner's communication theory is described in these terms. This discussion may be summarized as follows:

Key concepts and postulates from Allport's theory:

Event: A point of contact between ongoing processes. Events do not partake of time and space; a single event is a dichotomizing, non-quantifiable happening and nothing more.


HIGHLY APPROVE
+ 4
+ 3
+ 2
+ 1
INDIFFERENT
0
- 1
- 2
- 3
HIGHLY DISAPPROVE
- 4
(A)
(B)
(C)
a
b
c
d
e
f
g
h

Schematic diagram showing the Return Potential Model for representing norms. (A) A behavior dimension; (B) an evaluation or return dimension; (C) a return potential curve, showing the distribution of approval-disapproval among the members of a social system over the whole range of an Actor's behavior. (Taken from Figure 1 of text.)

Ongoing: A continuous process which closes on itself through a cycle of operation.

Ongoing-event cycle: The fundamental structure of any phenomenon; a series of ongoings and events which tends to close on itself to form a cycle.

Tangency of cycles: Contact or interaction of ongoing-event cycles in a common event.

Compounded cycle: A series of tangent ongoing-event cycles which itself tends to close to form a new cycle.

Autonomy: The energy-level of a cycle at which it maintains itself as a structure. This tends to coincide with that level at which the cycle is in equilibrium with the environment.

Energic closure: The coming to equilibrium of a cycle's energy level with those of adjacent cycles with which it is in contact.

Kinematic closure: The closing of a cycle.

Description of Gerbner's model in Allportian terms:

Someone: Any human being can be thought of as a very high order ongoing-event system or structure.

Perceives an event: The pattern of light disturbance in the atmosphere, caused by a fire, contacts the eye and transmits energy to the latent ongoing-event cycles in someone that had been formed by previous experience with fire, and brings their energy levels up to autonomy where they can operate as a structure in transmitting energy to the reaction cycle that follows.

And reacts: Reaching for the phone is composed of a series of ongoings and events that comes to closure in bringing the phone up to someone's ear and mouth.

In a situation: The community in which the incident occurs is a structure of cycles of ongoings and events.

Through some means: The telephone system is a structure of cycles of ongoings and events.

To make available materials: The administration of the telephone system is a structure that determines whether someone and his neighbor can afford phones and whether they are kept in working order.

In some form: The pattern of the words that someone says to his neighbor on the phone is a series of ongoings and events that we can assume, for the present, close in on themselves to form a cycle. It operates as a structure in transmitting energy to the latent house on fire structure within the neighbor.

And context: The context in which this behavior occurs is the structure of the friendship of someone and his neighbor.

Conveying content: The content conveyed is the latent house on fire structure within the neighbor that is re-energized or brought up to its autonomous level.

Of some consequences: The structure of the action taken by the neighbor in putting the fire out is the consequence of someone having called him. (Modified from p. 126.)

This description is illustrated on the following page.

Conception of Model: Since Gerbner's theory is taken to be a model and is used to represent communication phenomena, the conception of model is representational and of the empirical characterization type.

21. Kjeldergaard, Paul M., "The Psychology of Language," in Review of Educational Research: Language Arts and Fine Arts, 1961, Vol. 31, No. 2, pp. 119-129.

Purpose of the Paper: The purpose is to survey recent theoretical developments in the psychology of language.

Model Presented: A theory of mediated generalization is presented and may be summarized as follows:

Definition:

Mediated generalization is what takes place when learning in one situation has a facilitation effect on the learning in a second situation, even though there is no direct connection between the elements of the two learning experiences. (pp. 119-120)

Schematic Representation:

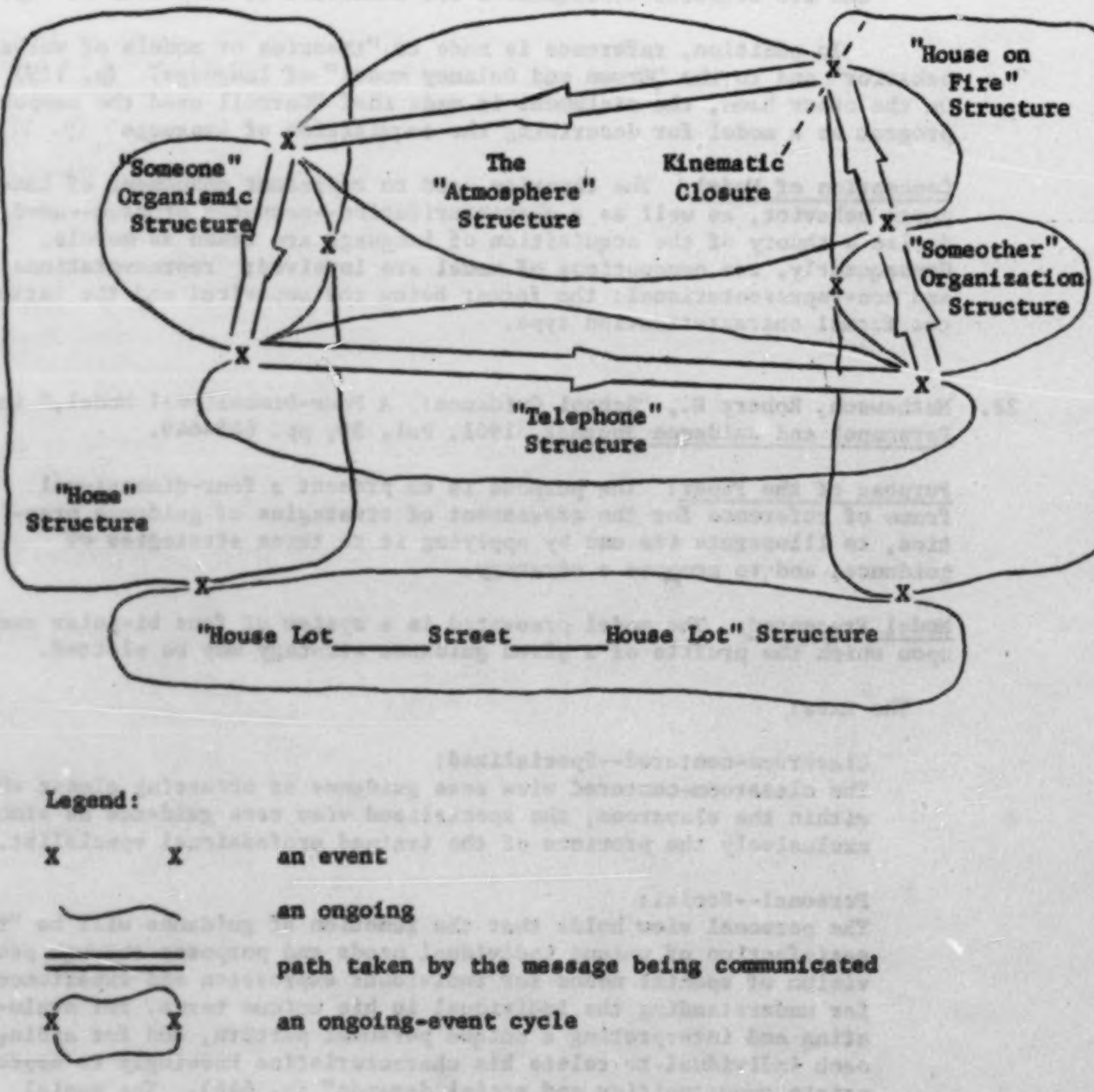
Prior Learning:

Stimulus A ⟶ Response C ⟶ (Stimulus consequences of C)
Stimulus B ⟶ Response C ⟶ (Stimulus consequences of C)

New Learning:

Stimulus A ⟶ (Implicit C) ⟶ (Stim. conseq. of C) ⟶ Response D
Stimulus B ⟶ (Implicit C) ⟶ (Stim. conseq. of C) ⟶ Response D

(p. 120)


"House on Fire" Structure
"Someone" Organismic Structure
The "Atmosphere" Structure
Kinematic Closure
"Someother" Organization Structure
"Telephone" Structure
"Home" Structure
"House Lot Street House Lot" Structure
X
Legend:
X X an event
an ongoing
path taken by the message being communicated
X X an ongoing-event cycle

(Modified from p. 127.)

Proposition:

> The connection between stimulus B and response D is accomplished, in part, during the A to D learning when the implicit response, C, and its stimulus consequences are connected to responses D. (p. 120)

In addition, reference is made to "theories or models of verbal behavior" and to the "Brown and Dulaney model" of language. (p. 119) On the other hand, the statement is made that "Carroll used the computer program as a model for describing the acquisition of language" (p. 119).

Conception of Model: The theories used to represent phenomena of language behavior, as well as a characterization--computer program--used to devise a theory of the acquisition of language are taken as models. Consequently, two conceptions of model are involved: representational and non-representational; the former being the empirical and the latter, the formal characterization type.

22. Mathewson, Robert H., "School Guidance: A Four-Dimensional Model," in Personnel and Guidance Journal, 1961, Vol. 39, pp. 645-649.

Purpose of the Paper: The purpose is to present a four-dimensional frame of reference for the assessment of strategies of guidance practice, to illustrate its use by applying it to three strategies of guidance, and to propose a strategy.

Model Presented: The model presented is a system of four bi-polar axes upon which the profile of a given guidance strategy may be plotted.

The Axes:

Classroom-centered--Specialized:
The classroom-centered view sees guidance as occurring almost wholly within the classroom; the specialized view sees guidance as almost exclusively the province of the trained professional specialist.

Personal--Social:
The personal view holds that the function of guidance will be "the satisfaction of unique individual needs and purposes through provision of special means for individual expression and experience, for understanding the individual in his unique terms, for evaluating and interpreting a unique personal pattern, and for aiding each individual to relate his characteristics knowingly to appropriate opportunities and social demands" (p. 646). The social view is chiefly concerned with meeting the needs of society.

Subjective--Objective:
The subjective pole emphasizes the self-defining and self-conceptualizing processes occurring within the pupil, while the

objective pole centers on the evaluation and interpretation of objective data obtained through the use of tested instruments.

Self-integrative--Prescriptive:
Self-integrative guidance assumes that the formation of percepts and concepts relating to adjustment, and their effective use in self-identity, is primarily the task of the individual himself. Prescriptive guidance emphasizes prescriptions or recommendations made by professionals at decision-points in the career of the individual.

These dimensions are acknowledged as all interrelated. Furthermore, it is recognized that there are other dimensions in guidance besides these, though these are seen as central.

Conception of Model: The four-dimensional system is a rudimentary theory of guidance behavior and as such would be used to represent educative phenomena related to guidance. The conception of model, therefore, is representational and of the empirical characterization type.

23. Mathieu, Gustave, "Language Laboratories," in Review of Educational Research: Instructional Materials: Educational Media and Technology, 1962, Vol. 32, No. 2, pp. 168-178.

Purpose of the Paper: The purpose is to review literature discussing the development and use of language laboratories.

Model Presented: The term 'model' is used in reference to the recorded voices of native speakers of languages, after which the learners are to pattern their own pronunciation of the language.

Conception of Model: This conception of model is non-representational and of the object type, since the recorded voices are objects to be represented in the other objects, the voices of the learners.

24. Mauch, James, "A Systems Analysis Approach to Education," in Phi Delta Kappan, 1962, Vol. 43, No. 4, pp. 158-162.

Purpose of the Paper: The purpose is to logically establish that use of the methods of systems analysis for comparison of alternative means of reaching educational goals can lead to discovery of ways to use more efficiently resources devoted to education.

Model Presented: Mention is made of "models of math programs" (p. 160), proposed ways of teaching mathematics. For each such proposed program, if one predicted both the cost per pupil and the amount of mathematics each pupil would learn, then it should be possible to select the program which would meet the mathematical objectives of the school at the lowest cost per pupil or to make the resources alloted to mathematics achieve the most learning per pupil. The result would be a model incorporating both educational and economic goals.

Conception of Model: Since the program is taken to be the model and it is used to represent ways of achieving goals, the conception of model is representational and of the empirical characterization type.

25. McClellan, James E., "Theory in Educational Administration," in School Review, 1960, Vol. 68, pp. 210-227.

Purpose of the Paper: The purpose is to offer an explanation of recent advances in theorizing in educational administration, to propose a theory of educational administration, and to discuss the probable outcomes for education of recent and current theoretical developments in educational administration.

Model Presented: The model presented is a theory of administration as decision-making in situations "analogous to those faced while playing poker in a group composed of friends and enemies. . . . Since there are many agents in this situation, the decision of any one agent becomes a datum to which the others must adjust if the system as a whole--that is, the game--is to be maintained intact.

. . . .

The administrative unit in education is defined as in a state of cooperative competition with a finite number of competitors. The purpose of the administrative unit is to maintain or improve its position relative to its competitors, and this purpose implies maintaining the integrity of the larger systems within which the competition occurs. . . .

To use theory of games requires that for any administrative unit, one can state a rank order of preference for alternative outcomes of the next move in the system, the next after that, and so on. . . .

. . . .

(Technically, a preference order ranks alternative states of the total system and not solely positions of one unit in the system.)

If we consider the school as an administrative unit in this sense, we still must make empirical predictions that are not deducible from the theories of decision-making. . . . But . . . our model of decision-making gives us a theoretical reason for saying that [these predictions are] relevant to administration of schools. . . . Thus predictions from other laws in the social sciences also acquire their administrative relevance from what they enable us to say about the probable outcomes of other moves for the preference orders of the school." (pp. 221-224)

Conception of Model: Since the theory of games as it is developed into a theory of administration as decision-making is taken to be the model and is used to represent phenomena relating to the administration of schools, the conception of model is representational and of the empirical characterization type.

26. Millar, Michael, "Some Roles of Subject Matter in Curriculum Inquiry," in School Review, 1960, Vol. 68, pp. 329-345.

Purpose of the Paper: The purpose is to state the need for a conceptual framework which would indicate the requirements for theory and guide research in curriculum and instruction, and to illustrate through a discussion of mathematics education some roles which subject matter might play in developing such a framework.

Model Presented: Millar criticizes as a model a formulation drawn from Ralph W. Tyler's Basic Principles of Curriculum and Instruction, Chicago: University of Chicago Press, 1950. This includes three categories conceived as fundamental in developing curricula or plans of instruction:

student-directed objectives (formulated with reference to both content and behavior),

the selection and organization of learning activities (designed to help the student attain the objectives), and

the evaluation of the learning activities (to determine whether the objectives are being attained).

Tyler views these categories as operative in a temporally consecutive, or linear, order.

Millar criticizes the ad hoc introduction of objectives and also the idea of linearity. He suggests that subject matter itself could function both in a regulative and formative role. The result would be considerations leading to a conceptual non-linear system of objectives and learning activities.

Conception of Model: Millar emphasizes that the kind of framework he discusses is not itself a theory, but a guide for the development of theory. Thus, it would appear that his conception of model is non-representational rather than representational. However, it is representational and of the empirical characterization type, for what he is proposing is the outlines or framework and so the beginnings of a theory which when completed would represent educative phenomena related to curriculum.

27. Mooney, Ross, A Conceptual Model for Integrating Four Approaches to the Identification of Creative Talent, A Report to the 1957 Research Conference on the Identification of Creative Scientific Talent, Salt Lake City, August 17-20, 1957, The Bureau of Educational Research and Service, The Ohio State University.

Purpose of the Paper: The purpose is to present "a perspective which is large enough to encompass all four /approaches to the problem of creativity/ within one system and deep enough to establish the interlocking function of all four" (p. 4). The four approaches arise from the following emphases: (1) environment, (2) the person, (3) the process, and (4) the product.

Model Presented: The perspective centers about the essential conditions for the existence of men which are stated in the language of dimensions and illustrated in the diagrams on the following page.

Dimensions:

(1) out, denoted by the outgoing arrows, to declare man's extension into his universe, his belonging to the whole;

(2) in, denoted by the incoming arrows, to declare man's centrality in his universe, his being integrative to the whole;

(3) out-and-in-and-out-and-in-again-and-again, denoted by the infinity sign, to declare man's sequential ordering of his universe, his continual coming to be (becoming) through give-and-take, incoming and outgoing;

(4) fit, denoted by the three lines at each end of the infinity sign, to declare man's selective ordering of his universe, his continual fitting of specific incomings and outgoings, his rendering potentialities actual in concrete sequential instances. (pp. 8-9)

Conception of Model: Since the model is a unifying idea used to represent all phenomena of life, not only that of man but that of a protozoan, it is representational and of the empirical characterization type. Furthermore, the qualification of model as conceptual, leads one to believe that there is a recognition of the other category of models according to what they are, i.e. object models.

28. Mort, Paul R. and Furno, Orlando F., Theory and Synthesis of a Sequential Simplex: A Model for Assessing the Effectiveness of Administrative Policies, Institute of Administrative Research, Teachers College, Columbia University, 1960.

Purpose of the Paper: The purpose is to make generally available the idea of the Sequential Simplex, certain specific formulations of the Sequential Simplex which have been developed and the use of these formulations, and ways of developing a Sequential Simplex.

Model Presented: The model presented is a specific formulation, 'Sequential Simplex Model B, 1955,' as an illustration of the use of the Sequential Simplex concept as an instrument of research. The concept

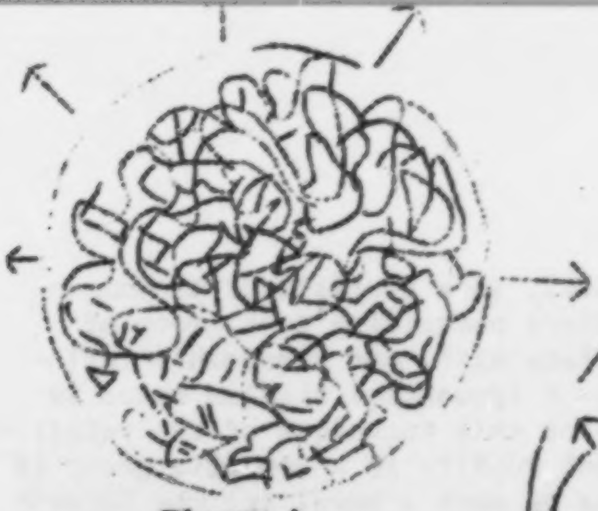


Figure A.
Composition within Universe: Energy Forms in Action

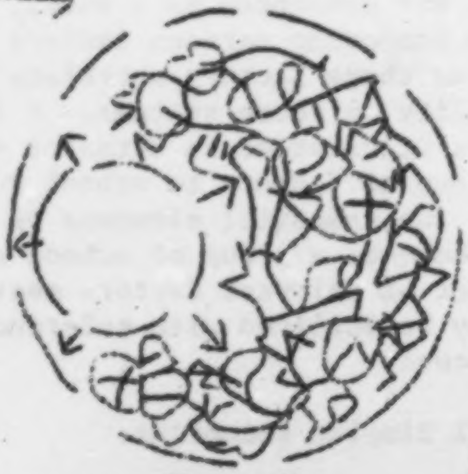


Figure B.
A Man's Outward Relation to Other Energy Forms

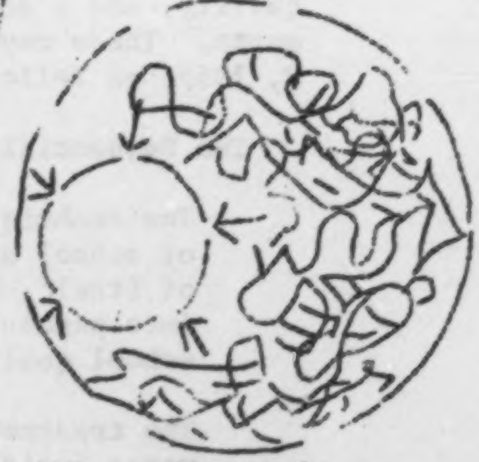


Figure C.
A Man's Inward Relation from Other Energy Forms

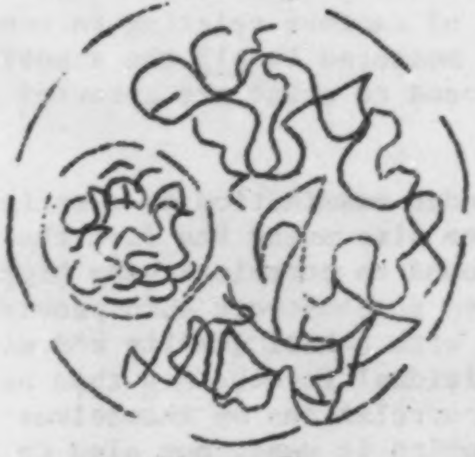


Figure D.
Composition within Man: Energy Forms in Action

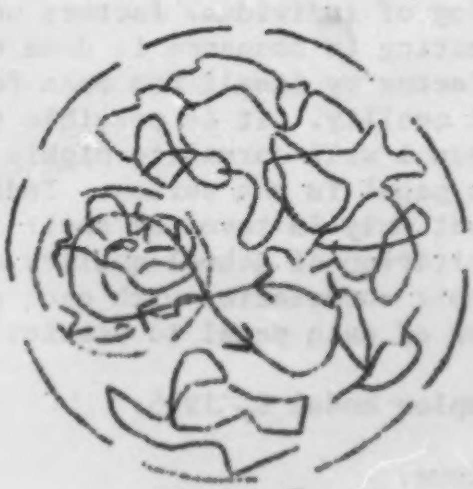


Figure E.
A Man's Sequential Transaction with Other Forms

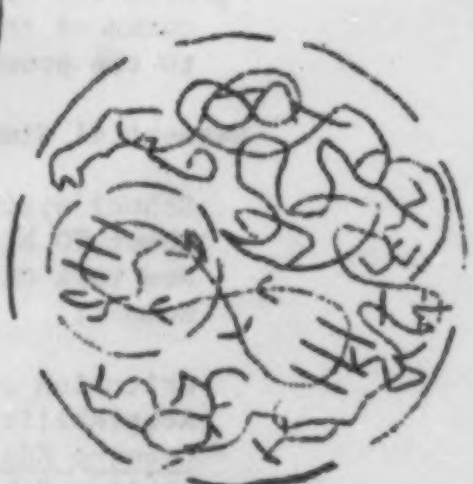


Figure F.
A Man's Selective Fitting during Transaction

Figures in re
Discussion of

ESSENTIAL CONDITIONS
FOR THE EXISTENCE OF MAN
June 20, 1956

itself, which is not presented as a model, is a statistical technique for grouping and comparing various factors pertaining to a group of school systems, as these factors correlate with, and presumably influence, school quality in those systems. A Sequential Simplex model is conceived to be a description in terms of this technique of the relation of a specific group of factors to school quality in a specific group of school systems. The essential elements of such a model are the Sequential Simplex technique, a group of school systems, a criterion of school quality, and a set of relevant factors measured with appropriate instruments. These may be outlined with reference to Sequential Simplex Model B, 1955, as follows:

The Sequential Simplex technique:

The technique has two basic features: the treatment of a group of school systems being studied as a statistical universe in and of itself, and the clustering of the traits under examination into panels which are considered to act in sequence as they affect school quality.

The treatment of a group of school systems as an independent universe avoids the difficulties of establishing either random or structured samples for the assessment of factors relating to school quality. The factors in question are measured in all the schools in the group, and the relationships found to exist are asserted to hold only for that specific group.

The assigning of individual factors under examination to a series of panels acting in sequence is done to circumvent the fact that no single factor by itself has been found to correlate very highly with school quality. It is possible to so construct such panels that each panel will correlate highly with school quality and with every other panel in the series. Individual factors may then be assessed, not only in terms of their correlations by themselves with the criterion of school quality which is used, but also in terms of their correlation with each panel and their contribution to the power of each panel to predict school quality.

Sequential Simplex Model B, 1955:

School systems:
About 70 high expenditure school systems in the Metropolitan New York City area, comprising the Metropolitan School Study Council.

Criterion of school quality:
Adaptability, as measured by the instrument presented in The Growing Edge, by Mort, Vincent, and Newell, New York: Metropolitan School Study Council, 1947.

Panels and factors under examination:
These are indicated in the diagram on the following page.

Use of the Model:

This model is designed particularly for the evaluation of the influence of various legal and administrative policies on school quality in the specific group of school systems studied. Eleven steps are prescribed for the evaluation of a given factor, as follows:

Step 1: Light From Related Studies
Comparison of the relationship found between the measure of the factor under study and school quality with similar relationships found in earlier studies.

Step 2: Light From Comparison With Critical Elements in the School Environment
Comparison of the measure of the factor under study with critical elements in the school environment represented by the measures in the model.

Step 3: Possible Sources of Disturbance in the Zero-Order Relationships
Identification of school-community environmental factors that run with or counter to the factor under study. This calls for a reclassification and examination of data collected in connection with Steps 1 and 2.

Step 4: Inferences as to Causation
Estimation from the data array of the possible way or ways in which the factor operates with the maze of other facts in the community and school environment.

Step 5: The Continuing Search For Possible Causes and Effects
Identification of the factors that may conceivably serve as intermediaries in bringing the force of the factor to bear on school quality.

Step 6: Summation of the Findings
Reassessment of the evolving theory as to how the factor operates (similar to Step 4).

Step 7: Determining the Unique Predictive Power of the Measure
Determination of the unique predictive power of the measure of the factor under study. In the preceding steps, the considerations were qualitative. Step 7 and the three steps immediately following (Steps 8, 9, and 10) apply quantitative measurement to the same considerations in order to refine the thinking in the evaluation of the theory of how the factor operates.

SEQUENTIAL SIMPLEX MODEL B-1955

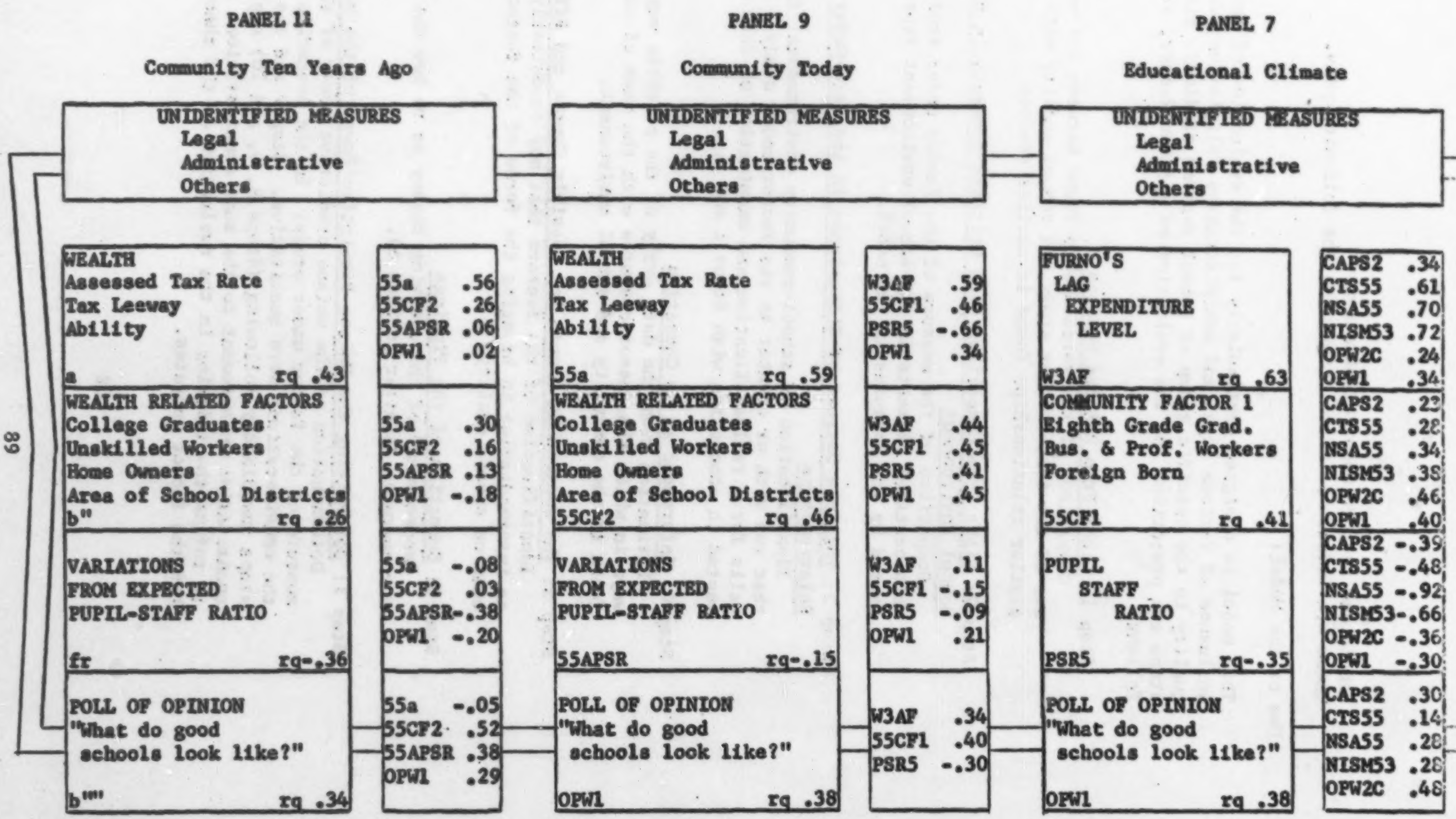
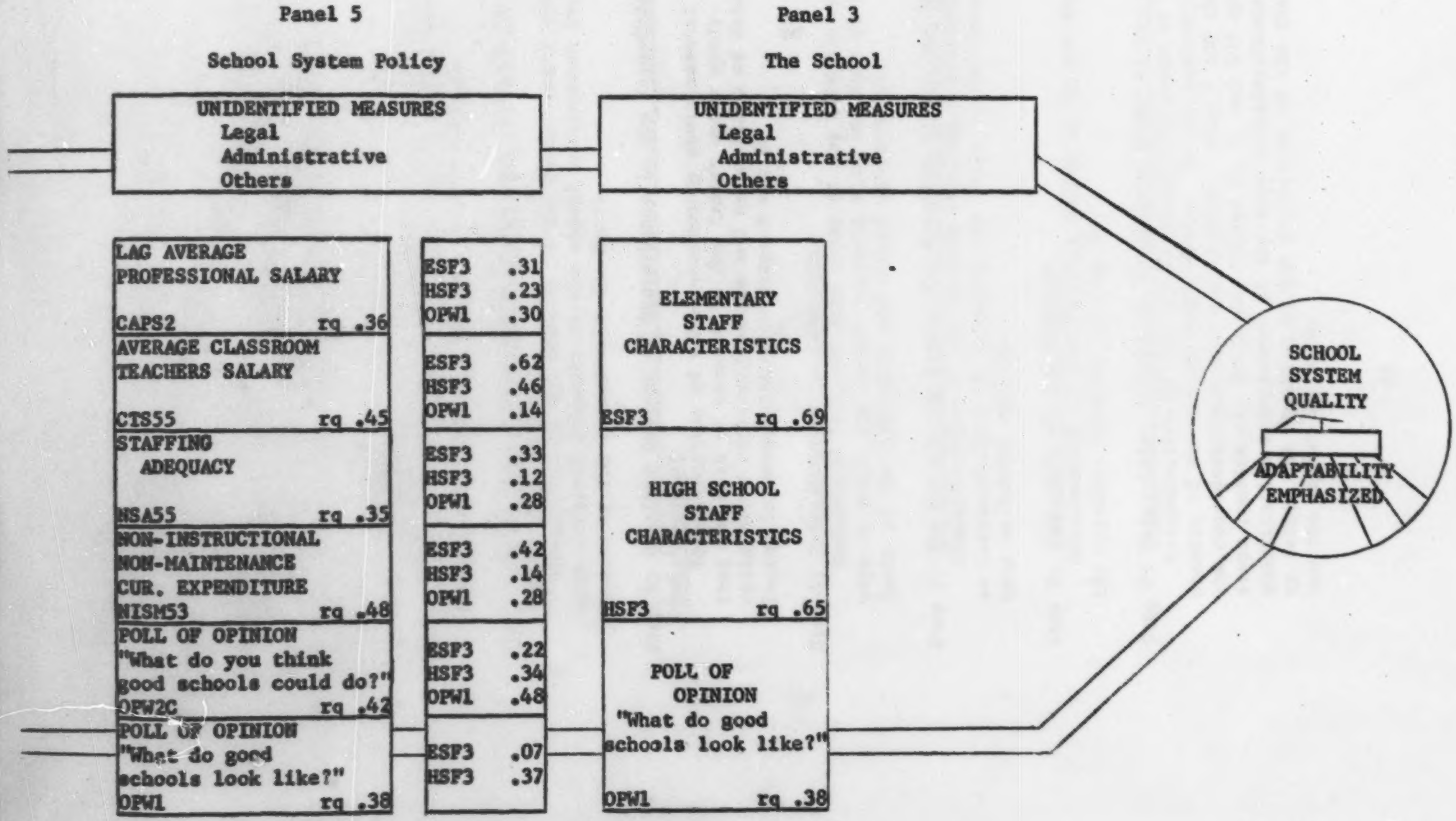

PANEL 11
Community Ten Years Ago
PANEL 9
Community Today
PANEL 7
Educational Climate
UNIDENTIFIED MEASURES
Legal
Administrative
Others
UNIDENTIFIED MEASURES
Legal
Administrative
Others
UNIDENTIFIED MEASURES
Legal
Administrative
Others
WEALTH
Assessed Tax Rate
Tax Leeway
Ability
a rq .43
55a .56
55CF2 .26
55APSR .06
OPW1 .02
WEALTH
Assessed Tax Rate
Tax Leeway
Ability
55a rq .59
W3AF .59
55CF1 .46
PSR5 -.66
OPW1 .34
FURNO'S
LAG
EXPENDITURE
LEVEL
W3AF rq .63
CAPS2 .34
CTS55 .61
NSA55 .70
NISM53 .72
OPW2C .24
OPW1 .34
WEALTH RELATED FACTORS
College Graduates
Unskilled Workers
Home Owners
Area of School Districts
b" rq .26
55a .30
55CF2 .16
55APSR .13
OPW1 -.18
WEALTH RELATED FACTORS
College Graduates
Unskilled Workers
Home Owners
Area of School Districts
55CF2 rq .46
W3AF .44
55CF1 .45
PSR5 .41
OPW1 .45
COMMUNITY FACTOR 1
Eighth Grade Grad.
Bus. & Prof. Workers
Foreign Born
55CF1 rq .41
CAPS2 .23
CTS55 .28
NSA55 .34
NISM53 .38
OPW2C .46
OPW1 .40
VARIATIONS
FROM EXPECTED
PUPIL-STAFF RATIO
fr rq-.36
55a -.08
55CF2 .03
55APSR-.38
OPW1 -.20
VARIATIONS
FROM EXPECTED
PUPIL-STAFF RATIO
55APSR rq-.15
W3AF .11
55CF1 -.15
PSR5 -.09
OPW1 .21
PUPIL
STAFF
RATIO
PSR5 rq-.35
CAPS2 -.39
CTS55 -.48
NSA55 -.92
NISM53-.66
OPW2C -.36
OPW1 -.30
POLL OF OPINION
"What do good
schools look like?"
b'''' rq .34
55a -.05
55CF2 .52
55APSR .38
OPW1 .29
POLL OF OPINION
"What do good
schools look like?"
OPW1 rq .38
W3AF .34
55CF1 .40
PSR5 -.30
POLL OF OPINION
"What do good
schools look like?"
OPW1 rq .38
CAPS2 .30
CTS55 .14
NSA55 .28
NISM53 .28
OPW2C .48

Figure 3. The schema for the control model idea of the Sequential Simplex Theory. It should be read as follows: The correlation between Staffing Adequacy, NSA55, and school quality is represented by the symbol rq -.35. The correlation between Staffing Adequacy and the separate measures in Panel 3 is shown in the block to the right of


Panel 5
School System Policy
Panel 3
The School
UNIDENTIFIED MEASURES
Legal
Administrative
Others
UNIDENTIFIED MEASURES
Legal
Administrative
Others
LAG AVERAGE PROFESSIONAL SALARY
CAPS2 rq .36
AVERAGE CLASSROOM TEACHERS SALARY
CTS55 rq .45
STAFFING ADEQUACY
NSA55 rq .35
NON-INSTRUCTIONAL NON-MAINTENANCE CUR. EXPENDITURE
NISM53 rq .48
POLL OF OPINION "What do you think good schools could do?"
OPW2C rq .42
POLL OF OPINION "What do good schools look like?"
OPW1 rq .38
ESF3 .31
HSF3 .23
OPW1 .30
ESF3 .62
HSF3 .46
OPW1 .14
ESF3 .33
HSF3 .12
OPW1 .28
ESF3 .42
HSF3 .14
OPW1 .28
ESF3 .22
HSF3 .34
OPW1 .48
ESF3 .07
HSF3 .37
ELEMENTARY STAFF CHARACTERISTICS
ESF3 rq .69
HIGH SCHOOL STAFF CHARACTERISTICS
HSF3 rq .65
POLL OF OPINION "What do good schools look like?"
OPW1 rq .38
SCHOOL SYSTEM QUALITY
ADAPTABILITY EMPHASIZED

the staffing adequacy measure. For example, the correlation between Staffing Adequacy and Elementary Staff Characteristics, ESF3, is .62. (From text of paper.)

Step 8: The Team-Mates Test
Quantitative measure of the strength of the relationship between the measure of the factor under study and the measures representing the facts of the community and school represented by the model.

Step 9: The Search For Inferences From a Study of the First Residuals
Reprocessing of the measure of the factor under study to bring into the open the characteristics of the measure that account for its relationships with quality.

Step 10: The Second-Derivative Test
Reprocessing of the data to identify the characteristics of the measure of the factor under study that have no predictive power for school quality (similar to Step 9).

Step 11: Final Evaluation of the Findings
Reexamination of the theory formulated in Steps 4, 5, and 6, bringing to bear on the operation of the factor any further light revealed by the quantitative Steps 7, 8, 9, and 10.

(pp. 22-23)

Conception of Model: Since the model is taken to be the characterization of the relation of a specific group of factors to school quality and is used to represent phenomena in a specific group of school systems, the conception of model is representational and of the empirical characterization type.

29. Newell, John M., Lewis, W. W., and Withall, John, "Use of a Communication Model to Study Classroom Behavior," Mimeographed paper presented at meeting of American Educational Research Association, 1961.

Purpose of the Paper: The purpose is to report the development of a set of categories for the classification of acts of communication, and their effectiveness in distinguishing between the communication behavior of teachers utilizing the concept of problem-oriented approach, the case study approach, and the learner-centered approach.

Model Presented: A set of categories for the classification of acts of communication is presented which is based upon a definition and analysis of communication, as follows:

> Definition of 'communication': "An interpersonal (or intrapersonal) process by which a person reduces the uncertainty of some state of affairs with another (or in some aspect of himself) by the detection of cues which seem to him to be relevant to that state of affairs." (p. 2)

Communication behaviors may be classified as sending-oriented or receiving-oriented.

Sending-oriented behaviors are associated with attempting to put an idea across to another. These may be subdivided into: output behavior--telling something to another, and feedback behavior--seeking to discover whether what has been told has been understood.

Receiving-oriented behaviors are associated with attempting to understand what another is saying. These may be classified as: input-behavior--listening, and confirmation behavior--asking questions to determine if one has understood what has been said.

The categories:

Receiving-oriented behaviors:
- Asks for information
- Seeks or accepts direction
- Asks for opinion or analysis
- Listens

Sending-oriented behaviors:
- Information-centered behaviors
  - Gives information
  - Gives suggestion
  - Gives direction
  - Gives opinion
  - Gives analysis
- Attitude-centered behaviors
  - Shows positive feeling
  - Inhibits communication
  - Shows negative feeling
  - No communication
- Awareness-indicating behavior
  - Perfunctory agreement or disagreement

Conception of Model: The set of categories used to represent acts of communication is taken to be a model; consequently, the conception of model is representational and of the empirical characterization type.

30. Page, Ellis B., "Behavioral Theory, Verbal Magic, and Education," in Educational Theory, 1962, Vol. 12, pp. 73-78.

Purpose of the Paper: The purpose is to show through the explication of the concept of experimental models the difficulties of deriving answers to educational problems concerning curriculum, methods, or guidance, from experimentation with mechanical models, or with animals, or with humans under contrived conditions.

Model Presented: Reference is made to the kinds of experimental models: sampling, substitutive, and illustrative. Page discusses the limitation of the substitutive model, and points out that the illustrative model is not an experiment (test) but a demonstration.

Conception of Model: Since the experimental model is used to represent the objects of interest and so to permit checking of a theory, the conception of model is representational and of the object type.

31. Rapacz, Richard V. and Kahn, Albert S., "Comparative Education," in Review of Educational Research: The Philosophical and Social Framework of Education, 1961, Vol. 31, No. 1, pp. 57-69.

Purpose of the Paper: The purpose is to review recent literature in comparative education.

Model Presented: Reference is made to Kandel's New Era in Education, which treats educational theories and practices of various nations in terms of their social, political, and economic systems as these operate within the cultural matrices of those nations. This work is said to be a model upon which later students, with more fully developed theories of culture, can build.

Conception of Model: It would appear that Kandel's theory is to be used to be represented in other theories yet to emerge. Thus the conception of model would be non-representational and of the empirical characterization type. However, if Kandel's theory is taken to set the framework within which other theorizing is to be done, then the conception of model as stated would not hold.

32. Shafer, Robert E., "Mass Communication," in Review of Educational Research: Language Arts and Fine Arts, 1961, Vol. 31, No. 2, pp. 197-207.

Purpose of the Paper: The purpose is to review research literature dealing with mass communication which has implications for education.

Model Presented: Reference is made to a need for "new conceptual and methodological models" (p. 199), and to "a classroom model projected as a social system" by Riley and Riley (p. 199). Sondel also is said to have projected a model of the classroom as a social system. Papers by Tannenbaum, Cunninghis, and others dealing with the development of survey techniques are cited in such a way as to indicate that Shafer considers such techniques methodological models.

Conception of Model: By 'conceptual model' Shafer would seem to mean a characterization used to represent educative phenomena related to mass communication. Reference to Sondel's and Riley and Riley's work indicates so. By 'methodological model' he would seem to mean a characterization used to represent the population of educative phenomena. Reference to survey techniques indicates so. Thus, the conception of model is representational and of the empirical characterization type.

33. Smith, B. Othanel, "A Concept of Teaching," in Language and Concepts in Education, ed. by B. Othanel Smith and Robert H. Ennis, Chicago: Rand McNally and Company, 1961, pp. 86-101.

Purpose of the Paper: The purpose is to criticize several current definitions of 'teaching,' and to present another definition of the term.

Model Presented: A pedagogical model based upon Tolman's "A Psychological Model," in Toward a General Theory of Action, ed. by Parsons and Shils, is presented. It is sketched as follows:

A Pedagogical Model

I Independent Variables (Teacher)		III Intervening Variables (Pupils)		II Dependent Variables (Pupils)
(1) Linguistic behavior (2) Performance behavior (3) Expressive behavior	⟶	These variables consist of postulated explanatory entities and processes such as memories, beliefs, needs, inferences, and associative mechanisms.	⟶	(1) Linguistic behavior (2) Performance behavior (3) Expressive behavior

(p. 91)

The arrows indicate the direction of causal influence. The action of teaching is an independent variable. Learning is an intervening variable which indicates its presence through pupil behavior, which is a dependent variable.

This model is not considered to be a complete theory of teaching, both because the three sets of variables are not completely set forth, and because, since pupil behavior also influences teacher behavior, the teaching process is a cycle of which the model portrays only half. The complete cycle may be symbolized as follows:

$$\| P_t \longrightarrow D_t \longrightarrow R_t | \longrightarrow P_p \longrightarrow D_p \longrightarrow R_p \| \longrightarrow P_t \longrightarrow D_t \longrightarrow R_t | \longrightarrow P_p \longrightarrow D_p \longrightarrow R_p$$

$$\| \longrightarrow P_t \longrightarrow D_t \longrightarrow R_t | \longrightarrow P_p \longrightarrow D_p \longrightarrow R_p \| \; . \; . \; . \; . \; . \longrightarrow \text{achievement}$$

(p. 92)

Where P_t is the teacher's perception of the pupil's behavior; D_t is the teacher's diagnosis of the pupil's educational condition; R_t is the action taken by the teacher; P_p is the pupil's perception of the teacher's behavior; D_p is the pupil's diagnosis of the teacher's state of mind; and R_p is the reaction of the pupil to the actions of the teacher. Double vertical lines mark off instances of the complete cycle; single vertical lines divide the cycle into the act of teaching, $\left|P_t \longrightarrow D_t \longrightarrow R_t\right|$, and the act of taking instruction, $\left|P_p \longrightarrow D_p \longrightarrow R_p\right|$.

Conception of Model: The theory constructed to represent the teaching process is termed 'a model.' Therefore, the conception of model is representational and of the empirical characterization type.

34. Suchman, J. Richard and Aschner, Mary Jane McCue, in Review of Educational Research: Growth, Development, and Learning, 1961, Vol. 31, No. 5, pp. 451-462.

Purpose of the Paper: The purpose is to review studies in the development of perception and cognitive processes.

Model Presented: The paper contains a single reference to "the construction of theories and models of perceptual mediation" (p. 451).

Conception of Model: The evidence is inadequate to enable a judgment as to what is meant by 'model,' but the phrase quoted above suggests a representational meaning of the empirical characterization type.

35. Sweitzer, Robert E., "An Assessment of Selected Theories of Administration," in Research in Educational Administration, ed. by S. P. Hencley, Cooperative Research Project No. F-2, 1962, pp. 68-99.

Purpose of the Paper: The purpose is to discuss problems and methods of assessing administrative theory, to propose a method, and to illustrate that method by applying it to two theories current in educational administration. The method proposed seeks areas of complementarity between two or more theories by spotting the directional properties of the theories, using these directional properties to determine the relationships of the theories to the interests of the investigator, and attempting to detect points of agreement between the theories. The theories used to illustrate this method of assessment are the Getzels-Guba nomothetic-idiographic model and Stogdill's input-output framework.

Model Presented: The term 'model' is used only in reference to the Getzels-Guba theory which is essentially the same as that presented in the papers by Coladarci and Getzels, Getzels, and Guba which are reviewed above--7, 11, and 15 respectively.

Conception of Model: On the basis of the way in which the term 'model' is used, the conception expressed here is identical to that elsewhere associated with the Getzels-Guba model: representational and of the empirical characterization type. However, in his discussion of the assessment of theories, Sweitzer suggests that two or more theories dealing with the same domain of data may be used to explicate and perhaps to evaluate each other, and to devise further propositions not contained in the original theories. This seems to be a non-representational conception of model.

36. Thompson, James D., "Modern Approaches to Theory in Administration," in Administrative Theory in Education, ed. by A. W. Halpin, Chicago: University of Chicago Press, 1958, pp. 20-39.

Purpose of the Paper: Thompson states his purpose to be the discussion of the following questions:

"(1) What do we hope to achieve through the use of theory?
(2) What are the sources of traditional theory?
(3) What are the criteria for administrative theory?
(4) Are we approaching an adequate theory?" (pp. 21-22)

Model Presented: Parsons' approach to administrative theory via social systems concepts, and applications of game theory to administration are mentioned as examples of models.

Conception of Model: It is probably the case that 'model' is used both in reference to theory used to represent administrative phenomena and to a pattern drawn from a related field for the building of administrative theory. At one point Thomspon distinguishes between theorizing as the result of deductive approaches based on a priori postulations and theorizing based upon models derived from a variety of sources, but at another point he refers also to the former as models. Whether he means to refer to representational models or to non-representational models or both, it is clear that there are empirical elements in the formulations he mentions.

37. van Egmond, Elmer, "Socialization Processes and Education," in Review of Educational Research: The Philosophical and Social Framework of Education, 1961, Vol. 31, No. 1, pp. 80-90.

Purpose of the Paper: The purpose is to review literature dealing with the nature of the socialization process, delinquency as a breakdown in the socialization process, and the school and mass media as agencies of socialization.

Model Presented: The term 'model' is used in the phrases 'identification model' and 'role model of the parents,' which refer to the function of parents in setting behavioral patterns which children adopt in the learning of social roles.

Conception of Model: Since the behavior of the parents is used as an object to be represented in the behavior of the children, the conception of model is non-representational and of the object type.

Conceptions and Evaluation

Table 1 on the following page summarizes the conceptions of model in the surveyed and abstracted literature dealing with educational theory. From the frequencies, the generalization that the prevailing conception of model is representational and of the empirical characterization type is patent.

Since the representational model of the empirical characterization type can have significance for educational theorizing in evaluating the results of such theorizing, one might be tempted to conclude that the prevailing conception of model has that significance. However, Table 2 on page 98 indicates that in only three abstracts was a conception of model related to the evaluating process, and of these three Table 3 on page 99 indicates that in only one was the conception of model representational and of the empirical characterization type. What one must conclude is that the prevailing conception of model has nothing whatever to do with the processes constituting or related to educational theorizing. Rather the conception of model is such that educational theory itself is seen as a model. In thirty-two instances, educational theory was viewed as a model of educational events. It was considered a characterization used to represent educational phenomena.

One can hardly quarrel with the prevailing conception of model on the grounds that it is not a logically legitimate conception. It is. Yet from the standpoint of doing educational theory, the prevailing conception

TABLE 1: CONCEPTIONS OF MODEL IN ABSTRACTS

Abstract Number	Conception of Model					
	Representational			Non-representational		
	Object	Characterization		Object	Characterization	
		Empirical	Formal		Empirical	Formal
1	0	1	0	0	0	0
2	0	1	0	0	1	1
3	0	1	0	0	0	0
4	0	1	0	0	0	0
5	1	1	0	0	0	1
6	0	1	0	0	0	0
7	0	1	0	0	0	0
8*	0	0	0	0	0	0
9	0	1	0	0	0	0
10	0	1	0	0	0	0
11	0	1	0	0	0	0
12	0	1	0	0	0	0
13	0	0	0	0	1	0
14	0	1	0	0	0	0
15	0	1	0	0	0	0
16	0	1	0	0	0	0
17	0	1	0	0	0	0
18	0	1	0	0	0	0
19	0	1	0	0	0	0
20	0	1	0	0	0	0
21	0	1	0	0	0	1
22	0	1	0	0	0	0
23	0	0	0	1	0	0
24	0	1	0	0	0	0
25	0	1	0	0	0	0
26	0	1	0	0	0	0
27	1	1	0	0	0	0
28	0	1	0	0	0	0
29	0	1	0	0	0	0
30	1	0	0	0	0	0
31	0	1	0	0	1	0
32	0	1	0	0	0	0
33	0	1	0	0	0	0
34	0	1	0	0	0	0
35	0	1	0	0	1	0
36	0	1	0	0	1	0
37	0	0	0	1	0	0
TOTAL	3	32	0	2	5	3

*The conception of model is representational, but not of the empirical or solely formal characterization type.

TABLE 2: ABSTRACTS IN WHICH CONCEPTION OF MODEL IS RELATED TO PROCESSES OF EDUCATIONAL THEORIZING

	Conception of Model Related in Abstract to		
Abstract Number	Doing Educational Theory		Evaluating Educational Theory
	Devising	Explicating	
2	1	1	0
5	0	1	1
13	1	0	0
21	1	0	0
30	0	0	1
31	1	1	0
32	0	0	1
35	1	1	0
36	1	1	0
SUBTOTAL	6	5	3
TOTAL	11		3

TABLE 3: CONCEPTIONS OF MODEL RELATED TO PROCESSES OF EDUCATIONAL THEORIZING

Conceptions of Model				Significance to Educational Theorizing Found in Abstracts		
				Devising	Explicating	Evaluating
Model	Representational	Object		▨	▨	2
		Characterization	Empirical	▨	▨	1
			Formal	▨	▨	0
	Non-representational	Object		▨	▨	▨
		Characterization	Empirical	5	4	▨
			Formal	1	1	▨
			TOTAL	6	5	3

' ▨ ' denotes logical impossibility, and so there are no instances.

is sterile. To do educational theory, what is required is a conception of model that is non-representational and of the empirical or formal characterization type. What are needed are points of view to be represented in, and thus allow the devising and explicating of educational theory. Those concerned with developing educational theory must come to such a conception of model; as Ausubel, Carroll, Griffiths, Kjeldergaard, Rapacz, Sweitzer, and Thompson seem to be doing. Furthermore, the non-representational conception must be given precedence over the representational conception. At least in this stage of development of educational theory, it is not the case that the representational conception has greater theoretical significance; as Griffiths has asserted:

> Although model is used in various ways, the fourth meaning above /a description of a set of data in terms of a system of symbols, and the manipulation of the symbols according to the rules of the system/ is probably the most precise and theoretically significant meaning of the word. It should be noted that this meaning is comparable to the definition . . . for theory.[13]

After more adequate educational theory has been devised and explicated is time enough to use the representational conception of model. Only then can we truly say that our theory represents educative phenomena.

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[13] Administrative Theory, New York: Appleton-Century-Crofts, Inc., 1959, p. 44.

SECTION III

EDUCATIONAL THEORY MODELS

AN EDUCATIONAL THEORY MODEL: GRAPH THEORY*

by Elizabeth Steiner Maccia

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*This paper first appeared as Occasional Paper 62-125, The Bureau of Educational Research and Service, The Ohio State University, 1962.

"Seven years and six months!" Humpty Dumpty repeated thoughtfully. "An uncomfortable sort of age. Now if you'd asked *my* advice, I'd have said 'Leave off at seven' -- but it's too late now."

"I never ask advice about growing," Alice said indignantly.

"Too proud?" the other enquired.

Alice felt even more indignant at this suggestion. "I mean," she said, "that one ca'n't help growing older."

"*One* ca'n't, perhaps," said Humpty Dumpty; "but *two* can. With proper assistance, you might have left off at seven."

I. INTRODUCTION

Through the assistance of the Rockefeller Foundation, two mathematicians, Frank Harary and Robert Z. Norman, were brought into association with the staff of the Research Center for Group Dynamics at the University of Michigan. This association led to the development of graph theory as a social science model. (1) Graph theory was utilized to formulate characterizations of relations of persons in groups. Education is a social science in so far as it deals with human group phenomena, although its distinction resides in the fact that the human group phenomena is within an institutional setting of a certain kind; namely, the school. (2) With this in mind, it was thought that graph theory also might be utilizable in formulating characterizations of relations of persons in groups within the school. (3) That is to say, graph theory could furnish an educational theory model. This paper presents the results of this thought.

The results will be not only the educational theory model, but the tentative educational theory as well. Unless such tentative translation of model to theory has been done, there is no justification in calling the model 'a theory model.' Furthermore, some relevance and fruitfulness of the theory will be indicated. Unless the theory bears such marks, there is no justification in not calling the theory, 'sheer speculation.' (4)

II. THE EDUCATIONAL THEORY MODEL

Graph theory is a formal characterization. By 'theory' is meant a system of statements; and by 'formal' is meant analytic. To understand what is meant by 'analytic,' one must realize that a group of statements can be considered a system provided the statements are interrelated. At least among the theories of interest in the context of educational theory models are those whose statements are so interrelated that some statements are consequences of others. Transformation rules would be rules for a given system of statements which determine under what conditions a statement is a consequence of another or other statements. If a system is made up of statements whose validity depends only upon the transformation rules and not upon the truth or falsity of other statements, it is analytic or formal. Stated more simply, a theory is formal when its validity depends upon one statement following according to rules from another or other statements and not upon whether it is descriptive of states of affairs or phenomena (actual or non-actual). One has but to recall Euclidean geometry as an example from school days of a formal theory. The validity of the Pythagorean Theorem did not depend upon its description of actual states of affairs determined by measurement, but upon its following according to rules from other theorems which in turn were derived from the postulates. As a model, therefore, graph theory is of the formal characterization type.

Graph theory will be used not to represent educational phenomena, the actual relations of persons in groups within a school; rather it will be used to develop characterizations of such phenomena, i.e. to develop educational theory. Thus, graph theory as a model is not only of the formal characterization type, but is non-representational. It is a point of view to be represented in characterizations of the relations of persons in groups within a school.

Not all of graph theory was used as the point of view for devising and explicating the educational theory that will be presented in the next section. (5), (6) Part of it was so used, and it is this part that constitutes the educational theory model.

A digraph consists of a finite collection of points, P_1, P_2, P_3, . . ., P_n, together with a prescribed subset of the set of all ordered pairs of points (a pair of points is ordered when one is first) which are directed lines. Figure 1 is a digraph consisting of a finite collection of points--A, B, C, D--together with a prescribed subset--$\overrightarrow{AB}$, $\overrightarrow{BC}$, $\overrightarrow{CD}$, $\overrightarrow{DA}$--of the set of all ordered pairs of points $\overrightarrow{AB}$, $\overleftarrow{AB}$, $\overrightarrow{AC}$, $\overleftarrow{AC}$, $\overrightarrow{AD}$, $\overleftarrow{AD}$, $\overrightarrow{BC}$, $\overleftarrow{BC}$, $\overrightarrow{BD}$, $\overleftarrow{BD}$, $\overrightarrow{CD}$, $\overleftarrow{CD}$.

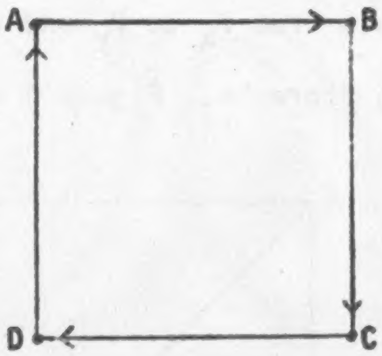

Figure 1

If and only if all ordered pairs of points are prescribed in the subset, the digraph is complete. Figure 1 becomes a complete digraph when $\overleftarrow{AB}$, $\overrightarrow{AC}$, $\overleftarrow{AC}$, $\overrightarrow{AD}$, $\overleftarrow{BC}$, $\overrightarrow{BD}$, $\overleftarrow{BD}$, $\overleftarrow{CD}$ also are prescribed, as in Figure 2.

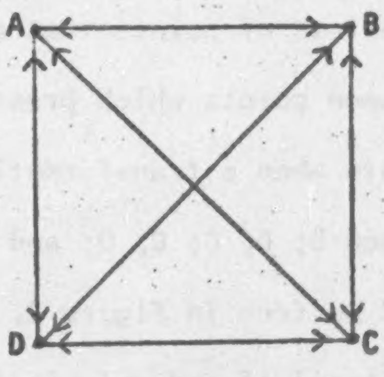

Figure 2

There is a directed path between two points, P_1 and P_2, when there are lines, $\overrightarrow{P_1P_x}$, $\overrightarrow{P_yP_z}$, . . ., $\overrightarrow{P_zP_2}$. In Figures 1 and 2 there is a directed path between A and D, $\overrightarrow{AB}$, $\overrightarrow{BC}$, $\overrightarrow{CD}$; in Figure 2, the directed paths between A and D also are $\overrightarrow{AD}$ and $\overrightarrow{AC}$, $\overrightarrow{CD}$. A semi-directed path joining P_1 and P_2 is a collection of points and directed lines which would become a directed path if the direction of some of the lines were reversed.

A digraph is strong if and only if for every pair of points, P_x and P_y, there exists a directed path from P_x to P_y and one from P_y to P_x. Thus, both Figures 1 and 2 are strong digraphs. Figure 3 also would be a strong digraph.

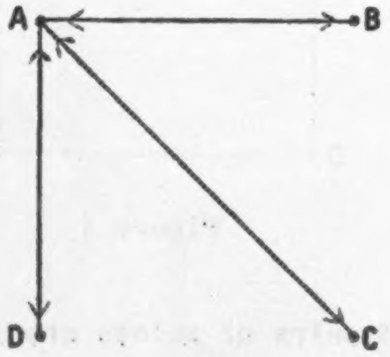

Figure 3

Figures 1 and 2 are automorphic digraphs, however, while Figure 3 is not. An automorphic digraph consists of points that are similar, i.e. there is a one-to-one correspondence between points which preserves the adjacency of all the points to each of the points when a transformation takes place. For example, in Figure 1, A could replace B; B, C; C, D; and D, A and the adjacency would be the same. This also would be true in Figure 2, but not in Figure 3.

A digraph is unilateral if and only if for every pair of distinct points, P_x and P_y, there exists a directed path from P_x to P_y or from P_y to P_x.

Since 'or' is not used in the exclusive sense, all strong digraphs would be unilateral. The converse does not hold. Figure 4 is a weak unilateral digraph.

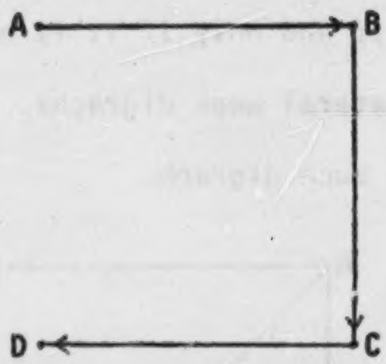

Figure 4

A digraph is disconnected if and only if the points can be divided into at least two subsets with no directed line joining any point in one subset to any point in the other subset, as in Figure 5.

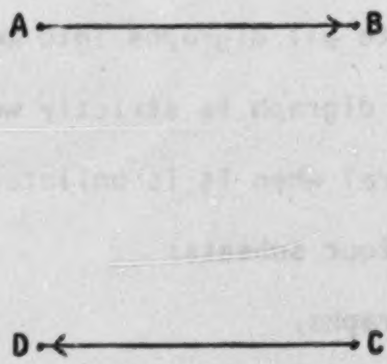

Figure 5

The digraph in Figure 6 is totally disconnected, since each of its points is an isolate.

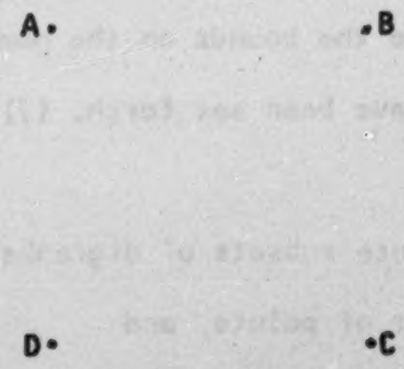

Figure 6

A digraph is weak if and only if it is not strong and not disconnected. Consequently, besides unilateral weak digraphs, there are non-unilateral weak digraphs. Figure 7 is one such digraph.

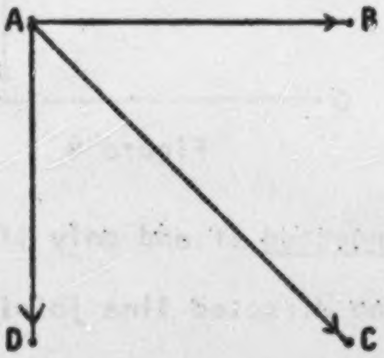

Figure 7

In order to separate all digraphs into mutually exclusive subsets with regard to connectedness, a digraph is strictly weak when it is not unilateral, and it is strictly unilateral when it is unilateral but not strong. Digraphs, therefore, will fall into four subsets:

C_0 - disconnected digraphs,

C_1 - strictly weak digraphs,

C_2 - strictly unilateral digraphs, and

C_3 - strong digraphs.

Theorems which give the bounds on the number of directed lines in a digraph in each category have been set forth. (7) Where

'D' denotes digraph,

'C_0, C_1, C_2, C_3' denote subsets of digraphs,

'p' denotes the number of points, and

'q' denotes the number of directed lines;

then

Theorem 0. If D is in C_0, then $0 \leqq q \leqq (p - 1)(p - 2)$,

Theorem 1. If D is in C_1, then $p - 1 \leqq q \leqq (p - 1)(p - 2)$,

Theorem 2. If D is in C_2, then $p - 1 \leqq q \leqq (p - 1)^2$, and

Theorem 3. If D is in C_3, then $p \leqq q \leqq p\ (p - 1)$.

These theorems are stated in another way and numerical examples are provided in the following table:

Category	Minimum Number of Lines	Maximum Number of Lines	Illustrative Ranges		
			$p = 3$	$p = 5$	$p = 7$
0	0	$(p - 1)(p - 2)$	0 - 2	0 - 12	0 - 30
1	$p - 1$	$(p - 1)(p - 2)$	2 - 2	4 - 12	6 - 30
2	$p - 1$	$(p - 1)^2$	2 - 4	4 - 16	6 - 36
3	p	$p(p - 1)$	3 - 6	5 - 20	7 - 42

Figures 8 and 9 illustrate graphically Category 1 for 4 points.

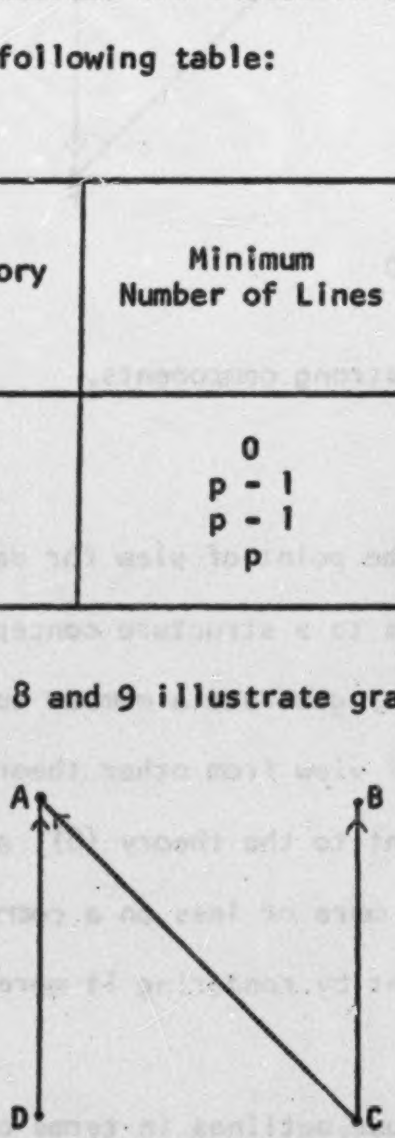

Figure 8: Lower Bound

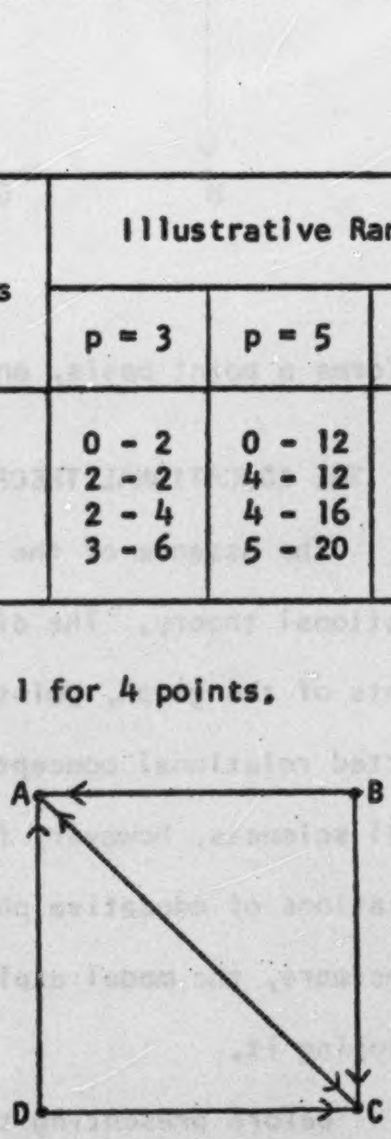

Figure 9: Upper Bound

A subdigraph of a digraph is a subset of points and directed lines of the digraph which constitutes a digraph. A strong component of a digraph is a maximal strong subgraph, i.e. one not properly contained in another strong subdigraph of D; similarly a weak component is a maximal weak subgraph. A point basis of a digraph is a minimal collection of points from which all points are reachable via a directed path. Thus, in Figure 10,

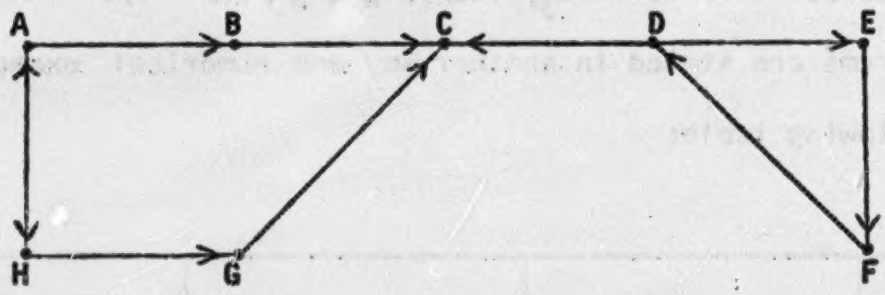

Figure 10

A,E forms a point basis, and AH and DEF are strong components.

III. THE EDUCATIONAL THEORY

The essence of the model furnishes the point of view for devising the educational theory. The digraph itself leads to a structure concept; the components of the graph, point and directed line, generate a member concept and a directed relational concept. Other points of view from other theorizing in the social sciences, however, furnish more content to the theory (8), as do characterizations of educative phenomena which are more or less on a common sense level. Furthermore, the model explicates this content by rendering it more precise and developing it.

Before presenting the theory, its broad outlines in terms of the essence of the model and the other content will be set forth.

In a classroom, both teacher and students behave. The object of the game (9), of course, is to achieve certain ends, i.e. aims of education or purposes for bringing teacher and student together in the classroom. Consequently, the behavior of the teacher and of the student must be of such a nature that the ends are achieved.

At first sight, one might say that the means to bring about such ends relate to the determinants of personality. The teacher and the student behave the way they do, because they have certain personalities. In so stating, one would be right in part. But let the teacher move out of the classroom into a faculty meeting or the students move out of the classroom onto a non-supervised playground, and one undoubtedly would be surprised at how differently they behave. What are the features of the two situations that produce such marked differences in behavior? The group seems to be implicated, and the concept of digraph leads to structure. The classroom group differs in structure from the faculty meeting group and non-supervised playground group. The answer, therefore, is to be sought in group structure. The teacher and student behave the way they do in a classroom, because of the structure of the classroom group. What is wanted is a theory of classroom group structure that can include a given aim or aims of education.

Since the concept of digraph leads to a structure concept, it leads through its components--point and directed line--to a member and directed relation concept. Groups involve persons, and so the theory will be in terms of interpersonal relationships. It could be in terms of relationships between positions (10), but the classroom group, unlike a group such as a corporation, does not have many clearly identifiable positions. The two identifiable positions that it does have, teacher and student, will delimit the interpersonal relations.

The teacher's role is that of an inducer of change in the behavior of a student. The student role, thus, is defined, i.e. that of an inducee. The concepts of inducer and inducee point to a concept of influence. Unless one person is related to another person in such a manner that one person can influence the other person, the roles of inducer and inducee cannot arise. The interpersonal relation called for is a directed one. One person directs himself to another person in order to bring about a behavioral change in that person.

Since aims of education are nothing other than statements of desirable behavior to be brought about in students, a given aim or aims of education can be included in a theory of classroom group structure in which the interpersonal relations are in terms of influence. Through influence, change in behavior which results in desirable behavior is possible.

Rather than restrict the theory to educational theory, it will be generalized to include group phenomena other than those of a school. That is to say, the theory will be so stated that groups besides those within a school, such as industrial groups, can be characterized as influence structures. Such statement will permit not only more adequate estimate of the relevance of the theory, but also might permit a theoretical contribution to social science in general.

The theory of the classroom group and other groups as influence structures will be presented formally, i.e. primitive terms, defined terms, postulates, and theorems will be stated. Nevertheless, some informal remarks will be included when they appear warranted.

Primitive terms: The following terms are taken as given and so not defined:

'person;'

'behavior;'
'feeling,'
'valuing,' and
'expecting;'
'force;' and
'time.'

The placing of 'feeling,' 'valuing,' and 'expecting' under 'behavior' indicates dimensions of behavior to be used in defining other terms of the theory. It is not the case that these are the only dimensions. 'Behavior,' consequently, must remain in our list of primitive terms. Furthermore, such incomplete specification of dimensions permits inclusion of a given aim or aims of education in the theory. For example, 'creative inquiry' might be included as a dimension of behavior to be brought about in student behavior through the influence of the teacher. In regard to 'force,' even though it is a non-definable term, it can be said that it is not reducible to 'coercion' in the usual sense of that term. This will be seen, as 'influence' other than 'coercive influence' is defined by means of 'force.'

Defined terms: All terms of the theory other than primitive terms must be definable by means of primitive terms, but for the sake of simplicity some will be defined through terms already defined. The defined terms are the following:

Definition 1. 'Change in behavior' is a difference in the behavior, a, of a given person, A; $a^{(t+1)} - a^{(t)}$, where 't' denotes time.

Definition 2. 'Resistance' is a force arising from a given person, A, against a given change in A's behavior, $a^{(t+1)} - a^{(t)}$, due to the behavior of another person, b.

Definition 3. 'Attraction' is a force arising from a given person, A, for a given change in A's behavior, $a^{(t+1)} - a^{(t)}$, due to the behavior of another person, b.

Definition 4. 'Direct influence' is a resultant force on a given person's behavior, a, due to the behavior of another person, b, which brings about a change in a, $a^{(t+1)} - a^{(t)}$.

Definition 5. 'Indirect influence' is a series of two or more direct influences, $x_1, \ldots, x_n$, due to two or more persons' behavior, a,b,...,k, such that x_1 is due to a and produces b, x_n is due to b and produces k.

Definition 6. 'Inducer' is a person, A, who directly or indirectly influences another person, B.

Definition 7. 'Inducee' is a person, A, who is directly or indirectly influenced by one or more persons, (B) v (B,C,...,K).

The above definitions, perhaps, will be more comprehensible through the following figures and discussion of them:

Figure 11: No Influence of A over B

Given in Figure 11 that A is a person whose behavior, a, resulted in greater resistance than attraction on the part of another person denoted by 'B;' then A is not an inducer; B is not an inducee; and B does not change his behavior due to A's behavior. In the context of a classroom, if A is the person assigned to the classroom as the teacher, and B is one of the persons assigned to the classroom as a student; then A does not teach B (A does not influence B), and B does not learn from A (B does not change his behavior due to A's behavior).

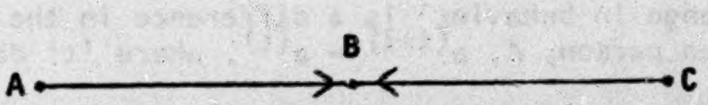

Figure 12: Direct Influence of A over B and C over B

Given in Figure 12 that A is a person whose behavior, a, resulted in greater attraction than resistance on the part of another person, B, and C is yet another person whose behavior, c, resulted in greater attraction than resistance on the part of B; then A and C are inducers; B is an inducee; and B does change his behavior, $b^{(t+1)} - b^{(t)}$, due to both A's and C's behavior, a and c. In the context of a classroom, if A is the person assigned to the classroom as the teacher, and B and C are two of the persons assigned to the classroom as students; then A directly does teach B (A directly does influence B) but so also does one of the students, C, (C directly does influence B), and B does learn directly from both A and C (B does change his behavior due to the behaviors of both A and C).

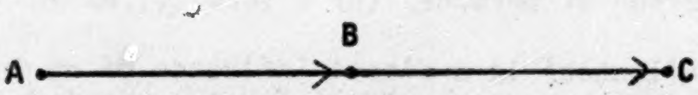

Figure 13: Direct Influence of A over B and B over C, and Indirect Influence of A over C

Given in Figure 13 that A is a person whose behavior, a, resulted in greater attraction than resistance on the part of another person, B, and B is a person whose behavior, $b^{(t+1)} - b^{(t)}$, brought about by a resulted in greater attraction than resistance on the part of yet another person C; then A is an inducer in relation to both B and C, while B is an inducer in relation to C; C is an inducee; and B does change his behavior, $b^{(t+1)} - b^{(t)}$, due to A's behavior, a, while C changes his behavior, $c^{(t+1)} - c^{(t)}$, due to B's behavior, $b^{(t+1)} - b^{(t)}$, brought about by A's behavior, a. In the context of the classroom, if A is the person assigned to the classroom as the teacher, and B and C are two of the persons assigned to the classroom as students; then A directly teaches B (A directly influences B) and indirectly teaches C through directly teaching B who directly teaches C (A indirectly influences C through directly influencing B who directly influences C), and B does learn directly from A (B does change his behavior due to A's behavior) and C does learn indirectly from A through learning directly from B (C does change his behavior due to A's behavior, because C changes his behavior due to B's behavior and B has changed his behavior due to A's behavior).

Definition 8. 'Coercive influence' is a direct influence of an inducer, A, upon an inducee, B, based upon B expecting behavior on the part of A which will produce effects for B which B cannot value.

Definition 9. 'Reward influence' is a direct influence of an inducer, A, upon an inducee, B, based upon B expecting behavior on the part of A which will produce effects for B which B can value.

Definition 10. 'Legitimate influence' is a direct influence of an inducer, A, upon an inducee, B, based upon B valuing A as an inducer because another person or persons, (C) v (C,D,...,K) value A as an inducer.

Definition 11. 'Expert influence' is a direct influence of an inducer, A, upon an inducee, B, based upon B valuing A as an inducer whether or not another person or persons, (C) v (C,D,...,K) value A as an inducer.

Definition 12. 'Identification' is a feeling of oneness of a person, A, with another person, B.

Definition 13. 'Referent influence' is a direct influence of an inducer, A, upon an inducee, B, based upon B identifying with A.

To illustrate these kinds of influence within a classroom setting, consider the following examples:

1. Johnny does not value rejection; and he expects rejection by the teacher, if he does not do what the teacher wants him to do. The teacher, thus, directly influences him.
2. Johnny does not value bad grades; and he expects a bad grade from the teacher, if he does not do what the teacher wants him to do. The teacher, thus, directly influences him.
3. Johnny does value acceptance; and he expects acceptance by the teacher, if he does what the teacher wants him to do. The teacher, thus, directly influences him.
4. Johnny does value good grades; and he expects a good grade from the teacher, if he does what the teacher wants him to do. The teacher, thus, directly influences him.

5. Johnny values the teacher as a teacher, because others value the teacher as a teacher. The teacher, thus, directly influences him.

6. Johnny values the teacher as a teacher, because he judges that the teacher knows better than he. The teacher, thus, directly influences him.

7. Johnny "likes" the teacher. The teacher, thus, directly influences him.

Examples 1 and 2 are of coercive influence, 3 and 4 of reward influence, 5 of legitimate influence, 6 of expert influence, and 7 of referent influence.

It will be noted that all of the kinds of direct influence, except referent influence, are defined in terms of valuing. The exception means, of course, that I reject the statement:

> Whenever X has influence over Y, there is some value with regard to which he can exercise influence over Y. (11)

Feeling is taken to involve no judgment, and so is non-cognitive behavior. On the other hand, valuing is, since it involves a criterion or criteria. Is not the greater strength of influence which is based on feeling over those based upon valuing due to feeling being non-cognitive?

Definition 14. 'Group' is K persons, A, B,...,K, where A is not K.

The above definition rules out a group of one person. There must be at least two persons. In a classroom, therefore, there must be at least two persons--there are usually more--for it to be considered as containing a group.

Definition 15. 'Disconnected group' is a group in which the persons are related so that at least one person is not influencing or being influenced, or the group can be divided into at least two subgroups of persons so that there is no person in one subgroup influencing or being influenced by a person in the other subgroup.

Definition 16. 'Strong group' is a connected group in which the persons are related so that for every two persons each is influenced by the other.

Definition 17. 'Unilateral group' is a connected group in which the persons are related so that for every two persons at least one is influenced by the other.

Definition 18. 'Weak group' is a connected group but not a strong group.

Definition 19. 'Strictly weak group' is a weak group but not a unilateral group.

Definition 20. 'Strictly unilateral group' is a unilateral group but not a strong group.

Definition 21. 'Automorphic group' is a group in which all the persons, A, B,...,K, are similar in regard to their influencing or being influenced.

Definition 22. 'Influence subgroup' is a group within a group which forms a strong group that is not contained in another strong group within the group, and which has one of its persons as one of a minimal group of persons within the group from which influence extends to all other persons of the group.

Let us assume a classroom group of four persons, A, B, C, and D, where A is the assigned teacher and B, C, and D are the assigned students. The persons, A, B, C, D, will be indicated by points with their respective alphabetic labels. Direct influence relations will exist between two persons, if there is a directed line, ⟶, between the points indicating them.

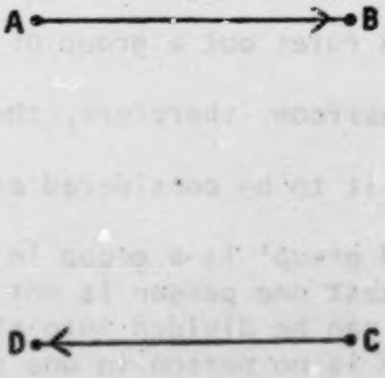

Figure 14: A Disconnected Classroom Group

A, the assigned teacher, directly teaches B and C directly teaches D, but A and B are isolated from C and D. The assigned teacher has no influence over C or D, nor is he influenced by C or D.

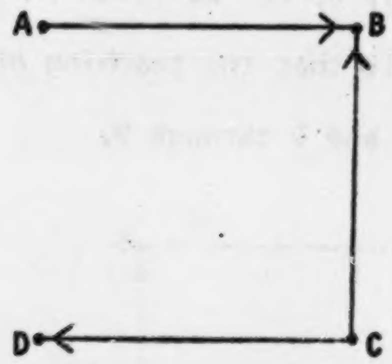

Figure 15: A Strictly Weak Classroom Group

The disconnected classroom group has been made a strictly weak one by adding a direct influence relation of C over B. Now C also teaches B. The assigned teacher still has no influence over C or D, nor is he influenced by C or D; but no person or persons are isolated.

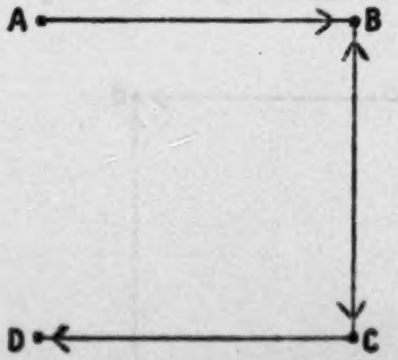

Figure 16: A Strictly Unilateral Classroom Group

By adding a direct influence relation of B over C, B directly teaches C. Now the assigned teacher can teach every student, also C and D indirectly through B and through B and C respectively. For every two persons at least one is taught directly or indirectly by the other: A directly teaches B, and indirectly C and D; B is taught directly by A, and B directly teaches C and indirectly D; C is taught indirectly by A and directly by B, and C directly teaches B and D; and D is taught indirectly by A and B, and directly by C. BC is an influence subgroup. The effect of the influence subgroup is that the teaching of B by C has to be taken into account in A's teaching of C and D through B.

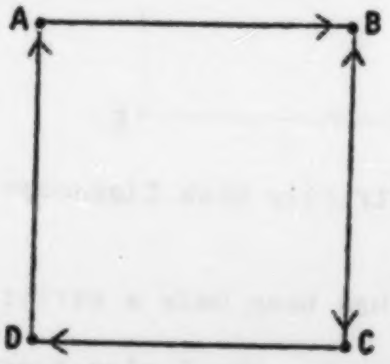

Figure 17: A Strong Classroom Group

By adding a direct influence relation of D over A, D directly teaches A. Now everyone directly or indirectly is teaching and being taught.

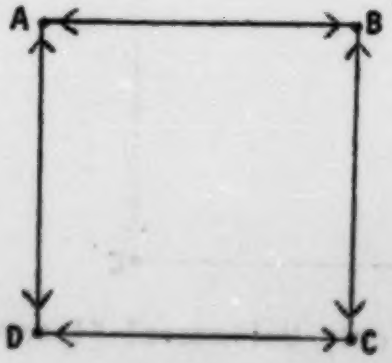

Figure 18: An Automorphic Classroom Group

By adding the following direct influence relations: A over D, B over A, and D over C, a group emerges in which the influence relations are similar for all. Each person is teaching directly and being taught directly.

Definition 23. 'Unit' is time required for K persons of a group A,B,...,K, to change their behavior to the point of equilibrium of all forces operating at the beginning of the unit.

Definition 23 divides the influence process in terms of behavioral change rather than in terms of physical time. In this manner, direct and indirect influence is taken into account. For example, the influence process in the classroom group depicted in Figure 16 involves three units. During unit one, the direct influences of A over B, B over C, C over B, and C over D are involved; during unit two, the indirect influences of A over C and B over D; and during unit three, the indirect influence of A over D.

Before turning to relating the terms in statements, postulates and theorems, mention should be made of the reason for the omission of 'power' from the list of primitive and defined terms. This is necessary, since 'power' is used extensively in the literature which will be referred to later in this paper when the relevance of the theory being presented is discussed. 'Power' means a capacity of an individual to influence another individual. Immediately, one is involved in a dispositional term, a state of a person. The difficulties surrounding the use of dispositional terms are too well known to recount here. It suffices to say that if the capacity can be dealt with in terms of its actualization, then the difficulties are surmounted. Parsons seems to treat influence as the actualization of power in the following quotation:

> Power we may define as the realistic capacity of a system-unit to actualize its interests . . . within the context of system-interaction and in this sense to exert influence on processes in the system. (12)

Nevertheless, I would resist the elimination of the term 'influence,' as Simon seems to do: "For the assertion, 'A has power over B,' we can substitute, 'A's behavior causes B's behavior.'" (13) 'Influence' is defined dyadically (two can), and so through directed graph theory is central in analyzing group structures.

Postulates: The postulates are statements which assert relationships between the terms. They are taken as given, and so cannot be derived from other statements of the theory.

Postulate 1. The strength of a direct influence, Δ, is a linear increasing function of the strengths of coercive influence, α, reward influence, β, legitimate influence, γ, expert influence, δ, and referent influence, ϵ; $\Delta = f(\alpha,\beta,\gamma,\delta,\epsilon)$.

In the figures thus far presented, when a directed line connected two points, the directed line represented a direct influence with no designation of the type or types constituting it. However, given a direct influence, $\overrightarrow{AB}$, constituted by all five types, instead of representing it as follows:

Figure 19

a more complete representation would be:

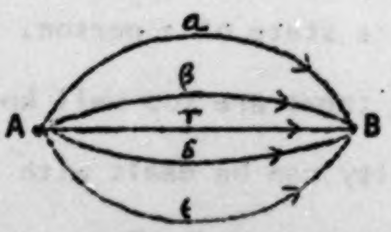

Figure 20

Clearly the strength of $\overrightarrow{AB}$ varies directly with $\overset{\alpha}{\overrightarrow{AB}}$, $\overset{\beta}{\overrightarrow{AB}}$, $\overset{\gamma}{\overrightarrow{AB}}$, $\overset{\delta}{\overrightarrow{AB}}$, and $\overset{\epsilon}{\overrightarrow{AB}}$. Notice that I am not stating in this postulate the way in which the strengths of α, β, γ, δ, and ϵ combine to produce the value of which Δ is a linear increasing function.

Postulate 2. The strength of a direct influence, Δ, is a linear increasing function of the strength of the resultant force, F, when the ratio of attraction to resistance is equal to or greater than 1;

$$\Delta = f(F^{(\frac{A}{R} \geq 1)}).$$

Postulate 3. The ratio of attraction to resistance in the case of coercive influence is less than the ratio in the case of reward influence.

Postulate 4. Given coercive influence, reward influence, legitimate influence, expert influence, and referent influence, only in the case of referent influence is the resistance 0.

Since 'direct influence' has been defined as a resultant force which produces a behavioral change, it is logical to assume that the direct influence of a teacher over a student will be stronger to the extent that the student is more attracted than does he resist. Furthermore, it is not difficult to assume that the student will resist punishment more than reward, and that when he identifies with the teacher he resists not at all.

Postulate 5. The strength of a direct influence, Δ, is an increasing function of the independence from behavior other than that of the inducee's of the basis or bases of the direct influence, I; $\Delta = f(I)$.

In the context of educational theory, Postulate 5 states that the more the teacher's influence depends solely on the student's behavior, the stronger will be the teacher's influence over the student.

Postulate 6. The following comparisons between coercive influence, α, reward influence, β, legitimate influence, γ, expert influence, δ, and referent influence, ϵ, according to the independence from behavior other than that of the inducee's of the respective basis, I, exist: $\alpha < \gamma$, $\beta < \gamma$, $\gamma < \delta$, $\gamma < \epsilon$.

Coercive influence and reward influence are based upon the inducer's behavior. The teacher, if he is to influence the student through rewards and punishment, must be able to administer them. The behavior of the student involved is expectation, but this expectation is dependent upon the teacher actually rewarding or punishing and continuing to do so. To a greater extent, legitimate influence is based upon the inducee's behavior. The student values the teacher as teacher. Nevertheless, this valuing depends upon the valuing of others. Other persons than the student value the teacher, and so make the teacher legitimate in the student's eyes. This process of making legitimate, however, is not as demanding in regard to reinforcement as is the expectation involved in coercive influence and reward influence. Indeed, such valuing can become internalized completely, and so require no reinforcement. When it does so, a basis for expert influence is present. The valuing of the teacher is the student's own on his own terms. The behavior of the inducee, thus, is central as a basis for expert influence. Referent influence, too, has this degree of independence from behavior other than the inducee's. Feeling of oneness arises within the student, and so he identifies with the teacher.

Postulate 7. For a given direct influence, x, there is a given range of the inducee's behavior within which a change in behavior can be induced, Φ.

Postulate 8. The range of the inducee's behavior within which a change in behavior can be induced, Φ, is an increasing function of the independence from behavior other than that of the inducee's of the basis or bases of the direct influence of the inducer, I; $\Phi = f(I)$.

To illustrate Postulates 7 and 8, consider two teachers: one whose direct influence is reward influence, and one whose direct influence is referent influence. Only behavioral changes that can be observed can be rewarded. The first teacher, therefore, can induce behavioral changes within a range restricted to the observable. Referent influence, however, has a greater range within which behavioral change can be induced. Whether the second teacher can observe the behavior or not, if the student understands that the teacher desires a change and, of course, if the behavior is possible for the student, then the student will do so because he identifies with the teacher. Notice that the influence which has the most independence from behavior other than that of the student's, referent influence, has the greatest range.

Postulate 9. Any attempt by a given person, A, to induce a given change in behavior, $b^{(t+1)} - b^{(t)}$, in another person, B, beyond the range of A's direct influence on B's behavior, ϕ, decreases the strength of A's direct influence on B, $\triangle$.

Consider the case of a teacher who attempts to influence a student to do what is impossible (leave off growing at seven). If the influence is based upon the expectation of reward (comfort), that expectation will go unfulfilled. The direct influence of the teacher upon that student will be decreased.

Postulate 10. At unit zero, t = o, each of K persons of a group A,B,...,K, has an initial behavior given by a real number.

Postulate 10 states that in a given group--a classroom group, for example--before influence occurs all persons have an initial behavior which can be quantified in a measurable manner.

Postulate 11. Influence is exerted only at discrete units, t=1,t=2,...,t=n.

To understand Postulate 11, consider once more the discussion of Definition 23 on page 119 of this report.

Postulate 12. The strength of the direct influence, $\triangle$, which a given inducer, B, exerts on a given inducee, A, during a given time unit, t = n, is a function of the size of the difference in their initial behaviors, $b^{(t)} - a^{(t)}$, which function increases to a maximum and then tends toward zero, $\triangle^{(t)} = f(b^{(t)} - a^{(t)})$.

Up to a point, the teacher will exert more influence if the discrepancy in his and the student's behavior is greater; but after that point is reached the teacher will exert less. This may mean, of course, that an extremely gifted teacher will not try to any great extent to teach the slow student if one is in his class, and the teacher whose intellectual gifts are not many will not try to any great extent to teach the gifted student if one is in his class.

Postulate 13. The change in behavior, $a^{(t+1)} - a^{(t)}$, is a function of the strength of direct influence, $\triangle$, which function increases to a maximum and then tends toward zero; $a^{(t+1)} - a^{(t)} = f(\triangle)$.

Postulate 13 states that, even though greater strength be exerted, more behavioral change might not result. Johnny, for example, might not learn more even though the teacher exerts greater influence.

Postulate 14. For a direct influence of a given strength, Δ_x, holding all other differences from the behavior, a, of an induce , A, except the behavior, b, of an inducer, B, constant, the change in A's behavior, $a^{(t+1)} - a^{(t)}$, is a linear increasing function of the difference in B's and A's behavior, $b^{(t)} - a^{(t)}$; $a^{(t+1)} - a^{(t)} = f(b^{(t)} - a^{(t)})$.

If, for example, a teacher exerts a direct influence of a given strength upon a student, and if one does not take into account the differences in behavior between that student and others in the classroom group; then the amount of learning that occurs increases directly with the size of the discrepancy between the teacher's behavior and the student's behavior before the direct influence occurs.

Postulate 15. The duration of change in behavior, $T_{(a^{(t+1)} - a^{(t)})}$ is an increasing function of the strength of a direct influence, Δ; $T_{(a^{(t+1)} - a^{(t)})} = f(\Delta)$.

In the context of the classroom group, Postulate 15 is an assertion that the greater the strength of the direct influence of the teacher over a student, the more the behavioral change or learning will persist through time.

Postulate 16. If a group is disconnected, then the minimum number of direct influence relations is 0, and the maximum $(K-1)(K-2)$, where K is the number of persons in the group.

Postulate 17. If a group is strictly weak, then the minimum number of direct influence relations is $K-1$, and the maximum $(K-1)(K-2)$, where K is the number of persons in the group.

Postulate 18. If a group is strictly unilateral, then the minimum number of direct influence relations is $(K-1)$, and the maximum $(K-1)^2$, where K is the number of persons in the group.

Postulate 19. If a group is strong, then the minimum number of direct influence relations is K, and the maximum $K(K-1)$, where K is the number of persons in the group.

See pages 106 and 107 of this report for a discussion which gives further meaning to Postulates 16 through 19.

Postulate 20. As the number of persons, K, in a connected group increases beyond some value of K, $K > n$, the group becomes disconnected.

For example, if the size of a class increases beyond some number, then there will be students in the class who are isolated from the rest of the class.

Theorems: Further statements which assert relationships between the terms are derived from the postulates or from other statements which are derived from the postulates. These are the theorems. Some of the theorems now will be stated.

Theorem 1. The following comparison between coercive influence, α, reward influence, β, legitimate influence, γ, expert influence, δ, and referent influence, ϵ, according to strength of direct influence, Δ, exists: $\alpha < \beta < \gamma < \delta < \epsilon$. /P2, P3, P4, P5, P6/ (14)

Theorem 1, of course, means that given five different teacher, A, B, C, D, and E whose influence is coercive, reward, legitimate, expert, and referent respectively, and given a student, F, the comparison of the strength of the teachers' influences over F would be as follows: $A < B < C < D < E$.

Theorem 2. The range of the inducee's behavior within which a change in behavior can be induced, Φ, is an increasing function of the strength of the direct influence, Δ; $\Phi = f(\Delta)$. /P5, P8/

Theorem 3. The following comparison between coercive influence, α, reward influence, β, legitimate influence, γ, expert influence, δ, and referent influence, ϵ, according to the range of the inducee's behavior within which a change in behavior can be induced, Φ, exists: $\alpha < \beta < \gamma < \delta < \epsilon$. /T1, T2/

If a teacher expects or is expected to bring about changes in the "whole child," affect the fullest extent of the student's behavior, then attention must be paid to the kinds of direct influence the teacher can exert. If a teacher can exert only coercive and reward influence; then the teacher cannot fulfill the expectation to the degree that he could, if he could exert the other kinds of direct influence. The kinds of direct influences compared according to the fulfillment of that expectation is as follows: $\alpha < \beta < \gamma < \delta < \epsilon$.

Theorem 4. Duration of change in behavior of an inducee, $T_{(a^{(t+1)} - a^{(t)})}$, is an increasing function of the range of the inducee's behavior within which a change in behavior can be induced, ϕ; $T_{(a^{(t+1)} - a^{(t)})} = f(\phi)$. [P15,T2]

Theorem 5. The following comparisons between coercive influence, α, reward influence, β, legitimate influence, γ, expert influence, δ, and referent influence, ϵ, according to the duration of change in behavior of an inducee, $T_{(a^{(t+1)} - a^{(t)})}$, exists: $\alpha < \beta < \gamma < \delta < \epsilon$. [T3,T4]

If a teacher expects or is expected to bring about learning that persists beyond school days, then the kind of direct influence involved in producing that learning is of utmost importance. The kinds of direct influence compared according to persistence of learning is as follows: $\alpha < \beta < \gamma < \delta < \epsilon$.

Theorem 6. If the number of direct influence relations is less than K-1, where K is the number of persons in the group; then there will be at least one person who is not influenced or is being influenced, or there will be at least two subgroups so that there is no person in one subgroup influencing or being influenced by a person in the other subgroup. [P17]

Theorem 7. If the number of direct influence relations in a group is less than (K-1), where K is the number of persons in the group; then influence cannot reach everyone from a single person. [P18]

Theorem 8. If the number of direct influence relations in a group is more than (K-1)(K-2), where K is the number of persons in the group; then there is a single person who can influence every other person in the group. [P17]

Theorem 9. If the number of direct influence relations in a group is more than $(K-1)^2$, where K is the number of persons in the group; then if the influence originates with any person, it will reach every other person and also the originator will be influenced. [P18]

Theorem 10. If the number of direct influence relations is K-1, where K is the number of persons in the group; then influence cannot originate with any person, reach everyone, and influence the originator. [P19]

By means of assumptions, Theorems 6 through 10 can be illustrated. First, let one assume that 30 persons--29 students and one teacher--are to be put together in a classroom. Secondly, let one assume that he knows that less than 29 direct influence relations do exist among the 30 persons. It would follow that if they are put together, at least one person or a subgroup of persons would be isolated within the classroom group. Furthermore, influence could not reach everyone from the teacher or from any other person in the group. If one changes the second assumption so that more than 812 influence relations exist, then there is a single person--the teacher or some student--who can influence every other person in the classroom group. If one changes the second assumption so that more than 841 influence relations exist; then if influence originates with a single person--the teacher, for example, it will reach every other person--each student--and also the originator--the teacher--will be influenced. If one changes the second assumption to exactly 29 influence relations, then influence cannot originate with any person--the teacher, for example, reach everyone--each student, and influence the originator--the teacher.

Theorem 11. In one unit, each of K persons of a group, A,B,...,K, who are influenced will change their initial behavior, a,b,...,k, until equilibrium where the resultant forces on each person's behavior equals 0. [P2,P13]

Theorem 12. In a strong group of K persons, A,B,...K, with initial behaviors, a,b,...,k, the persons will reach a final common behavior, Z, given by $Z = p_1a + p_2b + \ldots + p_nk$, where each of the coefficients, $p_1, p_2, \ldots, p_n$, is between 0 and 1 and $p_1 + p_2 + \ldots + p_n = 1$. [P10,P11,P14,T11]

Theorem 13. In a strong automorphic group of K persons, A,B,...,K, with initial behaviors, a,b,...,k, the persons will reach a final common behavior, Z, at the arithmetic mean; $Z = 1/K(a + b + \ldots + k)$. [T12]

At this point, it must be apparent that another model is being introduced, Markov chain theory. The relative influences in a strong group can be represented by a stochastic matrix. A stochastic matrix is one in which the sum of the entries in each row is 1 and the entries are non-negative. From this characterization of a stochastic matrix arises the conditions relating to the coefficients which give the relative influence of persons in a strong group, where all the direct influences are of equal strength. An illustration should help to clarify this theorem. (15) Assume a classroom group of three persons which is strong, but not automorphic, represented as follows:

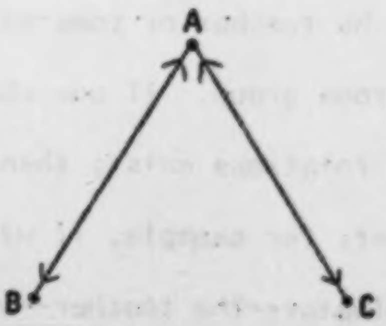

Figure 21: A Strong Non-automorphic Classroom Group

A's behavior, a, is determined 1/3 by a, 1/3 by b, and 1/3 by c; B's behavior, b, is determined 1/2 by a, and 1/2 by b; and C's behavior is determined 1/2 by a, and 1/2 by c. The following stochastic matrix represents these facts:

$$\begin{array}{cc} & \begin{array}{ccc} a & b & c \end{array} \\ \begin{array}{c} a \\ b \\ c \end{array} & \begin{pmatrix} 1/3 & 1/3 & 1/3 \\ 1/2 & 1/2 & 0 \\ 1/2 & 0 & 1/2 \end{pmatrix} \end{array}$$

Figure 22: Relative Influence after One Time Unit

If a stochastic matrix is raised to the nth power, it is still stochastic. The nth power, M^n, of the above matrix gives the relative influence after n time units.

The assumption is that for a large enough n, the influence of each person is stabilized.

$$M^n = \begin{pmatrix} .42 & .29 & .29 \\ .42 & .29 & .29 \\ .42 & .29 & .29 \end{pmatrix}$$

therefore, $Z = .42a + .29b + .29c$ for the classroom group depicted in Figure 21. If we add an influence of B over C and C over B, then the strong group becomes automorphic, as shown in Figure 23.

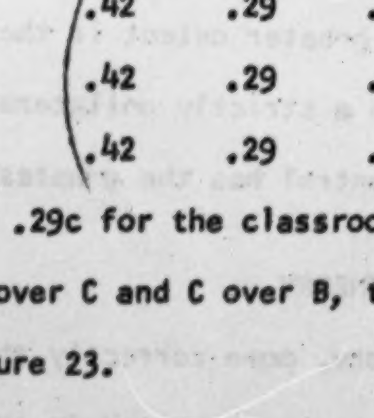

Figure 23: A Strong Automorphic Classroom Group

Now all persons in the group have equal influence, and $Z = 1/3(a+b+c)$. That is to say, the final behavior of the group is at the arithmetic mean.

Theorem 14. If a group has exactly one influence subgroup, then it has a final common behavior of the influence subgroup itself. [T12]

Theorem 15. If all the influence subgroups of a group have the same final common behavior, then all the persons attain this final common behavior. [T12]

Theorem 16. In a strictly unilateral group without an influence subgroup, the final behavior of the group is in agreement with one person's initial behavior. [P10,P11,P14,T11]

If a classroom group has only one influence subgroup, then the final common behavior--learning--will be the final common behavior--learning--of the influence subgroup. However, if other influence subgroups are present in the classroom group, then the final behavior of all persons will not be common--learning will not be the same, unless all of the influence subgroups have the same final behavior--same learning. Surely, if a teacher is expected to control learning, he can do so to a greater extent if there is only one influence subgroup of which he is a member. In a strictly unilateral group without an influence subgroup, the expectation of control has the greatest possibility of fulfillment.

IV. SIGNIFICANCE OF GRAPH THEORY

The educational theory, more correctly the social science theory of which the educational theory is a part, presented in the last section is far from completed. It is quite tentative. Enough development, however, has been undertaken to establish graph theory as an educational theory model. (16) Furthermore, the discussion which accompanied the definitions, postulates, and theorems has indicated the fruitfulness of the theory emerging from the point of view of graph theory. Some of the postulates and the stated theorems or yet other derivable theorems when related to the context of the classroom become hypotheses which can be checked. Finally, if relevance of the tentative theory can be indicated, then one can be certain that graph theory is not a model for sheer speculation.

The overall characterization of the classroom group as an influence structure (17) seems to be borne out in terms of the interpersonal perceptions of teachers and students. Jenkins and Lippitt reported that more teachers stressed respectfulness and obedience on the part of students than other qualities, while more students stressed fairness on the part of the teacher than other qualities. (18) The teachers saw themselves as influencing the students, provided the students recognized them as legitimate and expert (respected them) and did not resist them (obeyed them). The students also saw the teacher as an influencer, but one whose influence rested upon reward and punishment. Fairness relates to the students' concern over the teacher's behavior in relation to their behavior. For example, will the teachers give them the grades they deserve? An interesting aspect of this study, highlighted by placing it in the context of the theory, is the difference in the bases of influence the teachers desire--bases related to expert influence and legitimate influence, and the bases that appear to operate--bases related to coercive influence and reward influence. The desire for the basis related to legitimate influence is supported further in the study by the teachers' stress on recognition and acceptance by the parents. If the parents value the teacher, then their children as students might value the teacher. The teacher might have then a basis for legitimate influence.

Studies support the strength of influence being a function of coercive influence, reward influence, legitimate influence, expert influence, and referent influence. Two experiments reported by Burdick, von Ekartsberg, and Ons substantiate the view that the influence of a power figure is a positive function of his control of reinforcing stimuli. (19) The strength of influence, therefore, appears to be an increasing function of the strength of coercive influence and reward influence. The greater strength of reward influence over coercive influence is indicated by McDavid. (20) He concluded that the more effective social approval is as a reward, the greater its incentive or motivational value. Since Baer has pointed out that the withdrawal of positive reinforcement is an effective technique of punishment (21); one can assume that as social approval becomes a reward rather than a punishment, the greater will be the attraction and the less the resistance by a student, and so the stronger the influence over his behavior. The strength of influence has been shown also to depend upon legitimate influence.

Brim found that mothers were more likely to try out advice given by a doctor the more they attributed high prestige to the role of the doctor. (22) In Raven and French's research, they found that the following hypotheses held: the more a person, A, perceives his group as supporting the influence position of another person, B, the more will A perceive that B has a legitimate right to that position; the more A perceives that B has a legitimate right to his position, the greater will be the attraction of A toward B; and the more A perceives that B has a legitimate right to his position, the more A will perceive that B is justified in prescribing behavior for him. (23) In another study by them, they found that an elected supervisor (one granted the legitimate right by the group) had more influence than one who assumed his position without benefit of election. (24) Gnazey reported that the reaction of other classmates to the teacher affected the classmates' perception of the teacher as expert, fair, etc. (25) Expert influence can be deduced from a hypothesis which checked out for Deutch and Gerard, i.e. the more uncertain the individual is about the correctness of the judgment of others, the less likely he is to be susceptible to informational social influence in making his judgment. (26) Gerard's study of the changing of opinion of a person who has reached an opinion in another group points to referent influence. If that person is highly attracted to, identifies with, the first group, then it is difficult to change his behavior, change his opinion. (27)

Coch and French reported that the efficiency rating of a clothes presser in a factory climbed above average for the group, but a plateau resulted when other workers of the group began to "scapegoat" her (coercive influence). When she was removed from the group, her production climbed to new heights. (28) Clearly, coercive influence does not produce a behavioral change which persists or endures. When the coercive influence was no longer present, the plateau did not persist. Furthermore, coercive influence does not have much independence from behavior other than that of the inducee's. The coercive influence depended upon the group punishing through "scapegoating," and not upon the clothes presser. Finally, one can infer that the range of behavior within which coercive influence can bring about a behavioral change is limited to observable behavior. The group could not punish the clothes presser for her attitude about production, but only for her producing. She probably did not change her attitude (coercive influence could not affect it), and so when removed from the group the attitude could display itself in increased production.

A study which in a striking way substantiates the fact that influence does bring about behavioral change was carried out by French and Synder. They found that the hypothesis--the effectiveness of an attempt by a member, A, of a group to bring about behavioral change in another member, B, of that group increases with increasing influence of A--was significantly confirmed for opinion changes ($r=.38$), changes in the certainty of these opinions ($r=.53$) and ($r=.29$), and the productivity of the group ($r=.42$). (29) While this finding indicates the relevance of asserting within the theory that behavioral change is an increasing function of the strength of influence, yet it does not indicate the limitation of this increase in terms of a maximum. This limitation is indicated, however, through what is known of learning curves.

The above review of the literature undoubtedly has established that the tentative educational theory is relevant. If parts of a structure are grounded and the structure is put together well, then it should stand. Nevertheless, let me deal with the relevance of yet two other facets of the theory: discrepancy of behavior as it relates to strength of influence and the behavioral outcome in a strong group. Festinger and Thibaut's experiments strongly support the hypothesis that when there is a range of opinion in the group, communications tend to be directed toward those members whose opinions are at the extremes of the range. (30) Stated in the general terms of the theory, the strength of influence is an increasing function of the difference in initial behaviors between the inducer and the inducee. The theory, however, has limited this increasing function in terms of a maximum. When the discrepancy is too great, the strength of the influence will fall off. While there are no studies known to me which justify this claim, nevertheless common sense does. Consider rule-of-thumb statements, such as "Gifted students especially require teachers of superior intelligence . . ." (31) Is the thought expressed that the behavior of a teacher of lesser intelligence will be too far removed from that of the gifted student, so that very little teaching (influencing), if any, will occur? Studies need to be done to change common-sense into scientific relevance. Turning finally to the behavioral outcome in a strong group, the literature substantiates that a uniform behavior, conformity, will be the outcome. (32) (33) (34)

With the establishment of the relevance of the tentative educational theory, it is patent that one is justified in concluding that graph theory is significant as a model for educational theory.

FOOTNOTES

(1) Dorwin Cartwright, Director, Research Center for Group Dynamics, "Preface," to Graph Theory as a Mathematical Model in Social Science by Frank Harary and Robert Z. Norman, Ann Arbor: University of Michigan, Institute for Social Research, 1953, p. iv.

(2) Even though some would insist that education is as broad as life (Dewey, et al.), and even though such insistence has justification on the grounds that human development in all settings may be viewed as learning; nevertheless there is merit in sorting out human development within the formal setting of the school for characterization. Such characterization is what I mean by 'educational theory.'

(3) There has been some use of graph theory in education in the form of sociograms. However, rather than being used to generate a theory of classroom group structure, it has been limited to graphic representation of the classroom group structure in terms of the expressed attraction of students to one another. Strangely, where the teacher fits into the group structure has not been of concern, at least in the representation in the form of sociograms.

(4) See "The Way of Educational Theorizing Through Models," by Elizabeth Steiner Maccia and George S. Maccia, in the first section of this report. This includes a discussion of relevance and fruitfulness.

(5) For a more complete treatment of graph theory and its applications, see espeically: Berge, The Theory of Graphs trans. by Doig, London: Methuen & Co., Ltd., 1962; and Harary and Norman, Graph Theory as a Mathematical Model in Social Science, op. cit.

(6) The excellent work of James Andris, graduate student in mathematics and research assistant on this project, in abstracting literature on graph theory and its use in the social sciences is acknowledged.

(7) Dorwin Cartwright and Frank Harary, "The Number of Lines in a Digraph of Each Connectedness Category," in SIAM Review, Vol. 3, No. 4, October, 1961.

(8) As will be seen from the formal presentation of the theory, I am particularly indebted to the work set forth in the following papers from Studies in Social Power, ed. D. Cartwright, Ann Arbor, Mich.: Institute for Social Research, 1959: John R. P. French, Jr. and Bertram Raven, "The Bases of Social Power," and Frank Harary, "A Criterion for Unanimity in French's Theory of Social Power;" and also in the following paper by French: "A Formal Theory of Social Power," in The Psychological Review, Vol. 63, 1956, pp. 181-194.

(9) A game is only trivial, if its purposes are.

(10) This follows T. M. Newcomb's distinction in which role is the behavior of the persons who occupy a position, and the position is recognized by the members of the group if it contributes to the group's purposes. The contribution represents the function of the position. See Social Psychology, New York: Dryden Press, 1959.

(11) This statement was made by H. D. Lasswell and A. Kaplan on p. 83 in Power and Society, New Haven: Yale University Press, 1950. My interpretation of this statement is seen to be justified in the light of its context. Consider other statements, as on pp. 83-84:

> The exercise of influence may rest on well-being, on the physical strength of the person exercising it, as in the forms of influence known as 'intimidation' and 'brute force,' for example. It may depend upon wealth, as in the case of bribery; on skill as in the influence of the expert; or on enlightenment, the influence of the sage or teacher. Influence may rest on power, as exemplified by indoctrination; or on respect, the influence flowing from reputation. Rectitude is an influence base in the case of moral authority; and affection is the influence exercised by friends and loved ones.

It also might be of interest to note that Lasswell and Kaplan set forth in these statements what ought to be the basis for the teacher's influence. My attempt is to hold the theory I am presenting open in relation to oughts.

(12) See p. 391 of Essays in Sociological Theory, Glencoe, Illinois: Free Press, Revised edition, 1954.

(13) See p. 22 of Models of Man, New York: Wiley Publishing Co., 1957.

(14) Symbols in brackets after theorems indicate basis of derivation, where 'P' denotes postulate and 'T' denotes theorem.

(15) See Harary, "A Criterion for Unanimity in French's Theory of Social Power," in Studies in Social Power, op. cit.

(16) It is difficult to leave off development at this point. As one works with graph theory as a model for educational theory, one sees how the model could be expanded through inclusion of other concepts of graph theory so that the theory could deal with such matters as the diameter of the classroom group, the number of levels it has, its degree of connectedness, its degree of balance, its vulnerability to splitting, etc. However, the first fifteen months of the construction of educational theory which is covered in this project deliberately leaves off with the construction of educational theory models. The construction of educational theory models entails just enough construction of educational theory, so that the model can be said truly to be 'an educational theory model.'

(17) From the final report of Cooperative Research Project No. 397, Teacher Influence, Pupil Attitudes, and Achievement it is apparent that Ned A. Flanders did not view the classroom as an influence structure through the eyes of graph theory. What he means by 'direct influence' and 'indirect influence' is not what is meant in terms of graph theory. His indirect teacher influence (limited in his research to teacher talk) from the standpoint of graph theory might be a direct influence. For example, does the teacher through asking questions directly relate to a given student so that he directly influences that student? Well, the teacher might, if there is a basis for such a direct influence relation. There is no consideration of such bases, although reward influence appears implicated in the so-called 'indirect influence' of praising. Indeed, one might assert that their results were due to including in the indirect category, direct influences which were influences because they had a basis, and in the direct category, direct influences which were really not influences or at least weak influences because they did not have a basis or little basis.

(18) D. Jenkins and R. Lippitt, Interpersonal Perceptions of Teachers, Students and Parents, Washington: National Training Labor Group Development, 1951.

(19) H. A. Burdick, R. von Ekartsberg, and H. Ons, "Two Experiments in Social Power," in Psychological Reports, Vol. 5, 1959, pp. 781-789.

(20) John McDavid, Jr., "Some Relationships between Social Reinforcement and Scholastic Achievement," in Journal of Consulting Psychology, Vol. 23, 1959, pp. 151-154.

(21) Donald M. Baer, "Effect of Withdrawal of Positive Reinforcement on an Extinguishing Response in Young Children," in Child Development, Vol. 32, 1961, pp. 67-74.

(22) O. G. Brim, Jr., "The Acceptance of New Behavior in Child-rearing," in Human Relations, Vol. 7, 1954, pp. 473-491.

(23) Betram H. Raven and John R. P. French, Jr., "Legitimate Power, Coercive Power, and Observability in Social Influence," in Sociometry, Vol. 21, 1958, pp. 83-97.

(24) Betram H. Raven and John R. P. French, Jr., "Group Support, Legitimate Power, and Social Influence," in Journal of Personality, Vol. 26, 1958, pp. 400-409.

(25) William J. Gnazey, "Effects on Classmates of a Deviant Student's Power and Response to a Teacher-Exerted Control Technique," in The Journal of Educational Psychology, Vol. 57, 1960, pp. 1-8.

(26) Morton Deutch and Harold B. Gerard, "A Study of Normative and Informational Social Influences upon Individual Judgment," in Journal of Abnormal and Social Psychology, Vol. 51, 1955, pp. 629-636.

(27) H. B. Gerard, "The Anchorage of Opinion in Face-to-face Groups," in Human Relations, Vol. 7, 1954, pp. 313-325.

(28) L. Coch and J. R. P. French, Jr., "Overcoming Resistance to Change," in Human Relations, Vol. 1, 1948, pp. 512-532.

(29) John R. P. French, Jr. and Richard Synder, "Leadership and Interpersonal Power," in Studies in Social Power, op. cit., pp. 118-149.

(30) L. Festinger and J. Thibaut, "Interpersonal Communication in Small Groups," in Journal of Abnormal and Social Psychology, Vol. 46, 1951, pp. 92-99.

(31) Merle R. Sumption and Evelyn M. Luecking, Education of the Gifted, New York: The Ronald Press Company, 1960, p. 233.

(32) K. W. Back, "Influence through Social Communication," in Journal of Abnormal and Social Psychology, Vol. 46, 1951. pp. 9-23.

(33) Leonard Berkowitz, "Group Standards, Cohesiveness, and Productivity," in Human Relations, Vol. 1, 1954, pp. 501-519.

(34) Jay M. Jackson and Herbert D. Saltzman, "The Effect of Person-Group Relationships on Conformity Processes," in Journal of Abnormal and Social Psychology, Vol. 57, 1958, pp. 17-24.

AN EDUCATIONAL THEORY MODEL: GENERAL SYSTEMS THEORY*

by George S. Maccia

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Ludwig von Bertalanffy wrote that in many fields of research trends were occurring towards generalized theories containing universal principles which would apply to any system. He proposed a new discipline called 'General Systems Theory.' (1) Unlike theories which are based on assumptions of linearity and additive combination of independent units, General Systems Theory is based on assumptions of non-linearity and complex interactions among the parts which make up the system. There is centering on the behavior of the system as a whole, and leaving the system intact. Characterizations are not of units one at a time.

Although much practice in education results from theories based on linearity, persons in the discipline of education are aware of the difficulties which arise from such an assumption. Theories based upon such an assumption lead the teacher to employ the findings of research so as to minimize interaction between functions measured. For example, teachers tend to treat, in a uniform fashion, students who have been classified as being in a certain category, and thus ignore interaction effects. However, even if we consider only students with identical I.Q., achievement scores, personality ratings, and other such measures, we still cannot ignore interaction. Unlike apples, students with identical measures add up to more than students with identical measures. There is interaction between one student and another, between each student and the teacher, between all the students, between all the students and the teacher, and between all of the group taken as a whole. Also there is interaction with oneself and with other aspects of the classroom environment other than persons. Furthermore, this interaction which takes place in a classroom takes place with increasing complexity in the school and in the school district. Such interaction makes for an organization of great complexity, one which does not lend itself readily to the characterization of variables one at a time. What is needed, therefore, is educational theory based upon an acceptance of complexity and interaction, and so involving characterizations which leave complexity and interaction intact.

General Systems Theory presents such a point of view for educational theory. Hence, it is a non-representational model for educational theory. Also it is a model which is empirical in nature, since the propositions of General Systems Theory deal with the behavior of non-living systems and organisms of low order. When Miller asserts that General Systems Theory is a "series of related definitions, assumptions, and postulates about all levels of system from atomic particles through atoms, molecules, crystals, viruses, cells, organs, individuals, small groups, societies, planets, solar systems and galaxies" (2), he is assuming what is still a hope, that eventually it will be a formal model for theory in all these realms. The discipline proposed by von Bertalanffy has not yet come about.

EDUCATIONAL THEORY MODEL

The characterization, properties, and action presented as the model are derived from several sources, but principally from James Miller (2) (3), A. D. Hall and R. E. Fagen (4), K. E. Boulding (5), and J. W. S. Pringle (6). A consideration of these sources will make apparent that in constructing the educational theory model there was deletion, alteration of terminology, additions, and ordering. So emerged a coherent point of view for educational theorizing.

Characterization of Systems

1. A system is a set of entities together with their properties and the relationships between the entities.
    1.1. The entities which make up a system may be viewed as given to man or constructed by man.

1.2. The entities of a system are a variety of parts.

1.3. Properties of entities are specifications of them.

1.4. Relationships of entities are connections between entities.

   1.41. In static relationships, the properties of entities do not change with time.

   1.42. In dynamic relationships, the properties of entities change with time.

2. Environment is the set of all entities which surround the system; whose action may effect the systom, and may be effected by the system. It also is referred to as the suprasystem.

3. The boundaries of a system are the regions which differentiate the system from the environment.

Properties of Systems

1. A system is a multisystem, if it has other systems (subsystems) as its entities.

2. A system is open, if it has input and output.

   2.1. Input is the sending of entities from the environment into the system.

   2.2. Output is the sending of entities from the system into the environment.

3. A system is regulated, if it has feedback.

   3.1. Feedback is the return of output to the system.

4. A system is adaptive, if exchanges between the system and its environment lead to continuance of the system.

5. A system is stable, if change in certain system variables remains within definite limits.

6. A system is compatible with its environment, if it survives.

7. A system has wholeness, if a change in any entity of the system effects changes in all other entities and effects a change in system action.

8. A system has independence, if a change in at least one entity of a system effects that entity alone and does not effect change in system action.

9. A system is degenerate, if it has independence in relation to all its entities.

10. A system has hierarchical ordering, if it contains a gradation of entities and entity relationships.

11. A system is centralized, if an entity or a set of the entities dominates the actions of the system.

12. A system is in progressive segregation, if, in time, changes in the system tend toward independence of the system.

13. A system is in progressive systemization, if, in time, independence tends toward wholeness.

14. A system is state-determined, if its uniquely determined path is independent of the way in which the system arrived at its initial state.

15. A system is in steady state, if progressive segregation and progressive systemization occur simultaneously and continue through time.

    15.1. Steady-state systems are adaptive and state-determined.

    15.2. In a steady-state system, the entities appear constant because the entities are being formed and destroyed at the same rate.

        15.21. The process of destruction of an entity and the process of reforming an entity are either or both subject to variation.

        15.22. The rate of formation and the rate of destruction of each entity depend upon environmental conditions and upon different functions of the entities present.

        15.23. Only those entities will persist which have a higher rate of formation or a lower rate of destruction than other entities.

        15.24. The formation of entities is not determined by the initial probability of formation. A very improbable entity can survive or replace previously existing entities.

        15.25. If there are irregularities in formation of entities, the system contains possibility for change.

        15.26. If there is no exchange of parts between entities of a system, an improbable event may persist in one entity and not in the other entities.

        15.27. If there are slight differences in the environments of different entities of a system, a new part may survive only in some of the entities.

16. A system contains randomness, if the variables which effect a given property are so numerable or so inaccessible that the action of the system is considered to be subject to chance.

Action of Systems

1. The principle of nucleation states that there is an entity about which the system grows.

    1.1. There is a minimum entity magnitude around which a system grows.

    1.2. The nucleus need not be homogeneous to the system which grows around it.

2. The carpenter principle states that in systems being built from entities of lesser dimension either the dimensions of the entities must be extremely accurate or there must be careful adjustment of entities to fit the plan of the structure of the system.

    2.1. A system which is highly organized is more limited in its growth than a system which is not highly organized.

3. The rate of growth of a system, within certain limits, is exponential.

    3.1. Exponential growth occurs in a steady-state system with unrestricted resource input.

4. As a system grows, the proportion of its parts cannot remain constant.

5. The growth of a system is limited by compensation for non-proportional change.

    5.1. Closure (the growth itself seals off growing edges) effects the system's compensation for non-proportional change.

    5.2. In relation to physical entities, those functions and properties which depend on volume tend to dominate increasingly those dependent on area, and those dependent on area tend to dominate increasingly those dependent on length. Thus, as a system grows in its physical dimension, it tends to become longer and convoluted.

6. The D'Arcy Thomson principle states that in any given moment the form of an entity or system is a result of its laws of growth up to that moment.

    6.1. A physical entity or system in its physical dimension which grows uniformly in all directions will be a sphere, which grows faster in one direction than others will be long, and which grows faster on one side will be a spiral.

7. The principle of equal advantage states that the advantage of a system or entities in a system is an inverse function of the relative number of systems or entities in that location.

8. The principle of demand states that if there are differences in advantage, the entities will tend to move from a low advantage location to a high advantage location.

9. The Pinocchio principle states that a sub-system set up by a system tends toward independence and may separate from the system.

10. Systems which survive perform at an efficiency for maximum output which is always less than maximum efficiency.

    10.1. The output variables of a system are always less than input variables.

11. There is always a constant characteristic alteration between input of a system and its output.

12. The alteration of a system is the sum of the effects of processes which subtract input and add output.

13. The action of a system is effected by the amount of its input.

    13.1. If input is high, some of the input will be omitted.

    13.2. If input is high, the system will filter input and react only to certain categories of input.

    13.3. If input is excessive, the system will ignore input entirely or employ means for cutting off input.

    13.4. If input fluctuates in intensity, the system will delay output during peak loads and catch up during lulls.

    13.5. If input remains high, the system output will be less precise.

    13.6. If input continuously increases, then strain is produced in the system.

        13.61. When a system is under strain, progressive segregation can increase restorative power.

        13.62. A centralized system under strain requires more effort for stability than a decentralized system.

        13.63. A system undergoing progressive segregation is more likely to collapse under continuing strain than a system undergoing progressive systemization.

13.64. The stability limits of a system for specific variables increases proportionately to the amount of input storage, if no strain is on the variable.

13.65. If strain is on a variable of a system, the stability limits increase proportionately to the amount of filtering or ignoring of the input.

13.66. Systems act to continuously increasing strain first by a lag in output, then by an overcompensating output, and finally by a catastrophic collapse of the system.

14. If a system does not feed back some of its output, its stability decreases until the system degenerates.

15. The output across a boundary of a system requires greater action than transmission of output between the entities of a system.

THE EDUCATIONAL THEORY: THE SCHOOL AS A MULTI-SYSTEM

From the model, an educational theory is generated. The outlines of the educational theory are depicted in Figure 2 on the following page. An aspect of the model is presented in Figure 1. One, of course, recognizes the cybernetic model which forms one aspect of the broad outlines of the General Systems Model.

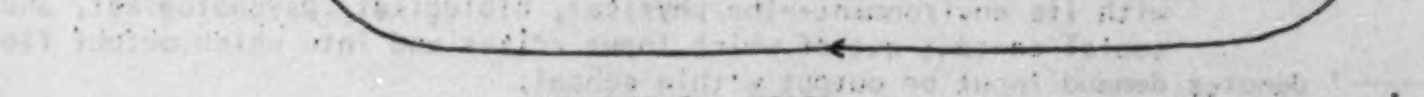

FIGURE 1: MODEL

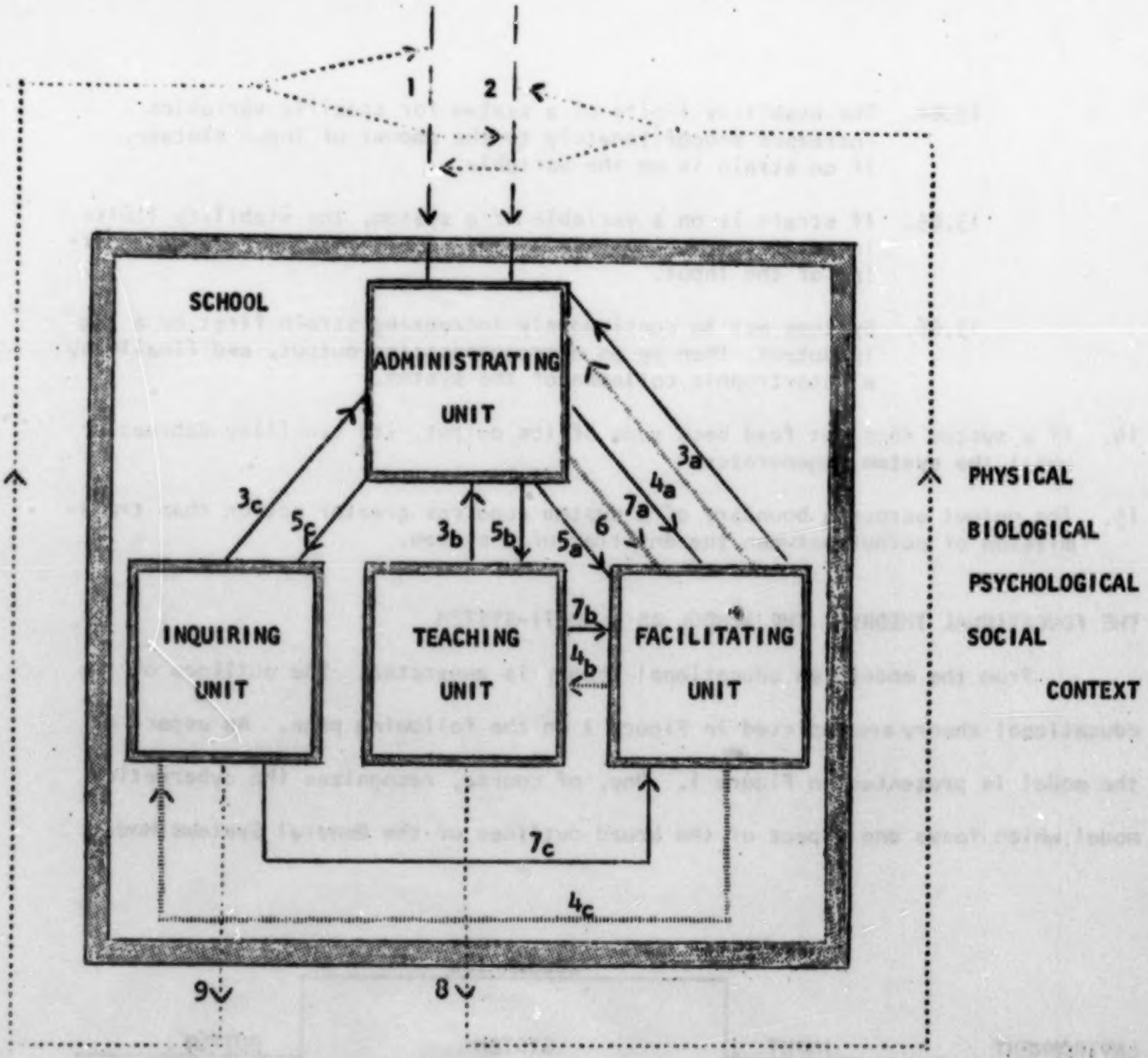
1
2
SCHOOL
ADMINISTRATING UNIT
INQUIRING UNIT
TEACHING UNIT
FACILITATING UNIT
3a
4a
7a
6
5a
5b
3b
3c
5c
7b
4b
7c
4c
9
8
PHYSICAL
BIOLOGICAL
PSYCHOLOGICAL
SOCIAL
CONTEXT

FIGURE 2: EDUCATIONAL THEORY

'▨' denotes boundaries of school and of each of its units, i.e. discontinuity with its environment--the physical, biological, psychological, and social context out of which input arises and into which output flows.
'———' denotes demand input or output within school.
'┅┅┅' denotes resource input or output within school.
'·······' denotes output of school.
'— —' denotes input of school.
Denotation of numbers is presented in Table 1 on the following page.

SYSTEM	INPUT		OUTPUT
	DEMANDS	RESOURCES	
School	1. Wanted Personalities, Wanted Role Takers, Wanted Structured Information, and Wanted Commodities	2. Persons, Information, Things, and Income	8. Personalities and Role Takers 9. Structured Information and Commodities
SUBSYSTEMS			
Administrating Unit	1. As above 3. As Output from Other Subsystems	2. As above 4a. Persons, Information, Things, and Income as Output from Facilitating Unit	5. Policies as Input into Other Subsystems 6. Resources as Input into Facilitating Unit 7a. Resource Demands as Input into Facilitating Unit
Facilitating Unit	7. Wanted Resources as Output from Other Subsystems 5a. Policies as Output from Administrating Unit	6. Persons, Information, Things, and Income as Output from Administrating Unit	4. Persons, Information, Things, and Income as Input to Other Subsystems 3a. Policy Demands as Input to Administrating Unit
Teaching Unit	5b. Policies as Output from Administrating Unit	4b. Persons, Information, Things, and Income as Output from Facilitating Unit	8. Personalities and Role Takers 3b. Policy Demands as Input to Administrating Unit 7b. Resource Demands as Input to Facilitating Unit
Inquiring Unit	5c. Policies as Output from Administrating Unit	4c. Persons, Information, Things, and Income as Output from Facilitating Unit	9. Structured Information and Commodities 3c. Policy Demands as Input to Administrating Unit 7c. Resource Demands as Input to Facilitating Unit

TABLE I: INPUT AND OUTPUT IN FIGURE 2

Characterization of the School as a System

System: As indicated in Figure 2, the school is a system. The parts of this system are the administrating unit, the inquiring unit, the teaching unit, and the facilitating unit. Properties of a school are characterized by the attributes of its units. Thus, all schools have the properties of administration, of instruction, of facilitation, and of inquiry. However, different types of schools and schools at different levels vary in the extent of the properties. To illustrate, the university has the property of inquiry to a greater extent than does the elementary school.

Relationships within and between the units of a school are both static and dynamic. Static relationships are between entities whose properties do not change. For example, in the teaching unit, the relationship designated 'instruction' does not change in general, because there are always persons characterized as teachers and students. On the other hand, dynamic relationships are between entities whose properties do change. In the teaching unit, there is change in the persons who are the teachers and students, in curricular materials, etc., and so there is change in relationships within the instruction relationship.

Environment: The environment or suprasystem of a school is the physical, biological, psychological, and social context in which it is located. The social context includes political, religious, fraternal, occupational, and other like social groupings. The context varies with the type and level of school. Thus, the political grouping involved could be the community or state or nation or a grouping of nations.

Boundaries: School boundaries are very thin regions in which the properties of the school change with great abruptness into the properties of the environment.

The physical boundaries of a school are the limits of property designated as 'school grounds.' These grounds usually are the site of school buildings, but are not limited to such grounds. Some schools, particularly schools for higher learning, have property located elsewhere which is used as field laboratories. The location could be many miles from the campus.

Psycho-sociological boundaries of a school are characterized by role differences in persons as staff, faculty, and students in a school and as members of other groups. There can be similarity of roles, as in the school and the home, but there are always characteristic differences. Physical location of persons in the school is not essential. Most schools have persons on boards of control who rarely are located in the school, but who come to the school for board meetings.

School boundaries are dynamic. They change and are subject to change. Some changes are temporary. An instance would be the treatment of public streets during certain times of the day and periods of the year as school grounds. Motorists using these streets are subject to special regulations, and traffic is often controlled by school employees and by students.

Properties of a School

Multisystem: From Figure 2, it can be seen that a school is a multisystem. The administrating, facilitating, teaching, and inquiring units are its subsystems.

Figure 2 might suggest that a part of one subsystem could not be a part of another. Although in large schools different parts occur in the different subsystems, such an arrangement of parts is not a necessary condition. All four subsystems may be viewed as existing within a one-room school. In a one-room school, however, the teacher becomes, at different times, the personnel of each of the subsystems. In the United States he would rarely be the sole person in the administrating unit, for here school personnel rarely serve as members of the board of control for the school in which they are employed.

Open System: Figure 2 makes apparent the openness of the school as a system. A school has environmental input, school output, and feedback. These properties of a school and its subsystems are characterized in Table 1.

From its environment a school receives, as input, resources and demands; but resource and demand are not exclusive categories of input. The distinction between resource and demand input is analytical, for resources may contain demands and demands may contain resources. Without persons a school could not exist, but no persons are received by a school who are free of genetic coding and of social conditioning. When persons enter a school, they carry with them demands for wanted personalities and social roles. Information processing is a function of a school; therefore, information is a necessary resource. With that resource, however, the school receives demands for wanted structured information.

In Table 1 the expected equivalence between input and output is suggested. This expected equivalence results in certain input-output relationships between a school's subsystems. The flow of these relationships is indicated by the numbered lines in Figure 2. Characterizations of them are given in Table 1.

From Figure 2 and Table 1 it can be seen that the administrating unit receives resources (income, things, persons, and information) and demands (wanted personalities, wanted role takers, wanted structured information, and--usually at higher levels of education--wanted commodities) from the school's environment. Subsystem output as wanted policies also is received by the administrating unit. From the facilitating unit, the administrating unit receives resources for its functioning from all the environmental resources it has turned over to the facilitating unit.

The output of the administrating unit is the policies received by the other subsystems, resources as input into the facilitating unit, and demands for resources into the facilitating unit.

The facilitating unit receives persons, information, things and income as resources and policies as demands from the administrating unit. The facilitating unit also receives demands for wanted resources as the output from the other subsystems. The output of the facilitating unit consists of resources (persons, information, things and income) which is received by the other subsystems. Facilitating unit output for policy is received by the administrating unit as part of its input.

From the administrating unit, the teaching unit receives policies; and from the facilitating unit, it receives resources. The output of the teaching unit consists of personalities and role takers received by the school's environment. Its policy demands are received by the administrating unit, and its resource demands are received by the facilitating unit.

The inquiring unit receives policies from the administrating unit and resources from the facilitating unit. The inquiring unit's output consists of structured information, and--depending upon the level of education in the school--commodities. Demands as inquiring unit output are for policy from the administrating unit, and for resources from the facilitating unit.

While the input-output characterizations in Table 1 hold for any school, the kind of personalities, roles, structured information, and commodities depends upon environmental contexts and upon the type and level of school.

Input demands into public schools will differ in certain respects from those into private schools. Into sectarian private schools come demands for religiously oriented personalities, while into non-sectarian private schools come demands for personalities and roles of the social and occupational classes it serves. Input into the public schools rarely contains, at least openly, demands relating to religious doctrine; nor does it contain demands for personalities and roles of, at least, the upper socio-economic group.

The input and output of a school depends also upon the level of the school. Input into an elementary school results in an emphasis on developing the child as personality, and on a child's role in the family and community. Few, if any, demands for structured information and commodities are received by an elementary school; and little, if any, structured information and few, if any, commodities are produced.

At the secondary level of education, demand for role takers begins to be emphasized over demand for personalities. The student as citizen, as worker in agriculture, business, or industry, and as sportsman appear in secondary school output. In order to aid in the production of wanted role takers, guidance personnel often are included in the school. Commodity production by a secondary school rarely occurs with high frequency in its output. Some commodities, resulting from means employed to develop certain role takers, are produced. The products of school shops are sometimes sold to the public. Athletic competition between some secondary schools approaches commodity output. Interschool boards of control are established to regulate this output, but facilities and procedures for marketing interscholastic sports are developed wherever such events occur.

In schools for higher education, demand for role takers clearly outweighs demand for personalities. Graduates are expected to be occupational role takers. Even the liberal art colleges expect to produce role takers, although they hope to do so with a less specialized curriculum. The generalist is seen as one who can take any role including an occupational role. Structured information (research) produced by the inquiring unit is represented in school output. Commodities at this level of education mainly take the form of monographs, books, and, sometimes, inventions.

The difference in school output according to the level of the school may be generalized as follows: school output decreases in personalities and increases in role takers, structured information, and commodities from lower to higher levels.

Regulation: Regulatory processes in a school are readily distinguished in Figure 2. Regulation occurs by output being fed back as input. Research as output is fed back as structured information. The feedback of personnel could be direct, i.e. a school might employ its own graduates. Such regulation occurs most frequently in small private schools, often sectarian ones; although it is not infrequent in universities. Personnel regulation in most schools is indirect, with their output effecting their input through legal and extra-legal agencies which specify qualifications and standards for school personnel, and even in some cases certify school personnel.

Regulation also occurs between the subsystems of a school. The output of one or more subsystems is input into another subsystem. Thus, the output of the administrating unit in the form of policies is fed into the other subsystems. In communicating policies, the administrating unit employs staff and faculty meetings and other types of discussion, and bulletins, reports, and other types of written communication. The teaching, inquiring, and facilitating units regulate this regulation by inputing policy demands into the administrating unit.

Adaptation: Adaptation of a school to its environment--adjustment of output to input so that a school may continue to exist--accounts for individual differences between schools of the same type and at the same level. Consider a public elementary school in different socio-economic environments. One whose input comes from middle socio-economic groups will tend to produce graduates whose personalities and roles are characteristic of those groups. One that is located in a lower socio-economic environment (e.g. non-consolidated rural school) will tend to produce graduates whose personalities and roles are characteristic of its environment. However, if the public elementary school is in a disorganized environment, as in a metropolitan slum area, then it is not highly adaptive, but adaptation does occur. For example, in a public elementary school in a metropolitan slum area to allow for home conditions which deprive children of sleep, teachers may permit children to sleep in class. Since home conditions are often not conducive to study, teachers may not assign homework. Disciplinary procedures customary to the home may be employed at school.

Stability: Stability in a school is dynamic in nature, an equilibrium process in which excess in one unit is followed by action by the other units to maintain equilibrium. Variability within and between the subsystems remains within limits. The input and output of the subsystems do not lose their distinctiveness.

The turnover of personnel in a public elementary school in a metropolitan slum area is an indicator of the instability of such a school. In such a school due to input demands, output of the subsystems cannot be adjusted within limits; and so the school no longer is a school. The teaching unit tends to be custodial--a place where children are in custody rather than a place where they are taught.

Compatibility: A school whose output fits in with the school's environment is a compatible one. One also can speak of the compatibility of the units of the school in relation to one another. Adaptation produces adjustment of output to input, and so output to environment--compatibility. Compatibility within limits produces stability. In order to have compatibility and stability, a school--like a man in space--might strive to construct an environment--like the constructed space capsule--that permits both. The public elementary school in the metropolitan slum area attempts to do this by orienting itself as a subsystem in the larger system of public elementary schools.

Wholeness: Unless a school has wholeness, a change in one unit brings about a change in the other units, adjustment of output to input cannot take place. No adaptation, compatibility, or stability is possible. Ordinarily, wholeness is most evident with changes in the administrating and facilitating units. In general, wholeness increases with the increase in the number of subsystems staffed by the same persons. A one-room school represents a unique example of wholeness in all subsystems.

Independence: The opposite of wholeness is independence. The school as a system does exhibit the property of independence. It is most evident in the personnel of the subsystems. Principals, teachers, researchers, maintenance personnel, students, etc. come and go with little effect upon school action.

Independence from the administrating unit in the functions of the teaching and inquiring units increases from the elementary school to the university. For example, academic freedom is rarely an issue in an elementary school. It is frequently an issue in a university.

Degeneration: A school becomes degenerate, if there is no wholeness, i.e. all its units are completely independent of one another. Such a school would have no relationships connecting its subsystems, and so no regulation. Equilibrating processes would not occur. The school would be unstable.

Hierarchical Ordering: As Figure 2 suggests, a school is hierarchically ordered. There are levels with the administrating unit at the highest one. In most schools, final decisions in relation to school policies are made by the administrating unit, but not without taking into account the demands of the community within and without the school. School policies are usually the result of an adjustment between environmental demand input and subsystem demand input into the administrating unit.

Centralization: Hierarchical ordering in a school suggests that a school's power is centered in the administrating unit. In the United States, legal power to effect school action is vested in boards of control. Frequently, boards delegate power to the administrating unit. In universities and colleges certain powers are vested in the teaching and inquiring units.

Regardless of school level, an administrating unit may delegate administrative powers to the other subsystems. Such decentralization occurs most frequently in larger schools and in schools which are subsystems in a school system. With decentralization, the subsystems increase in independence. The property of independence increases with decentralization, and decreases with centralization.

Progressive Segregation: Progressive segregation characterizes a school in which changes within it tend toward independence of its units. This process appears to be correlated with growth in school age population which produces growth in the size of schools.

Progressive Systemization: If progressive segregation continues, relationships between the units in a school break down and the school degenerates. To prevent such degeneration, processes moving the school toward wholeness must occur. A school that is moving toward wholeness has the property of progressive systemization. A school tending toward centralization would have the property of progressive systemization.

States: A school to be a school must be state-determined. The general outcomes of a school listed in Table 1 characterize school output, regardless of the nature of its establishing agency. For example, Harvard College took the path of an academic institution for higher education even though it was established to halt "increase of opinion" in Massachusetts. In its growth from Harvard College to Harvard University its output of structured information, like this output of all colleges and universities, tended to "increase opinion" rather than halt it. It remained a school.

If a school is in steady state, it is state-determined and it is adaptive. Furthermore, if the school has independence and wholeness, because both progressive segregation and progressive systemization are occurring, it is in steady state and will not degenerate.

Even though a school is in steady state, there is a continuous formation and reformation within its subsystems. Within the teaching unit, for example, groups are brought together as classes, changes occur in these classes, and eventually these classes cease to exist. At different times, there will be variation in relation to the rate of formation and reformation. At the beginning and at the end of teaching terms, the rate of formation and reformation of classes will be greater. Nevertheless, the overall rate of formation in comparison to destruction of classes must be greater or classes will disappear within the teaching unit.

Environmental conditions greatly effect the rate of formation and reformation. Consider what happens in a system of schools. (The school is viewed as a subsystem within a system of schools.) Population growth of a community usually results in the growth of a school. If the growth in population is rapid and sustained, an existing school will increase in size resulting in the building of additional schools. In areas where resources are insufficient for expansion, several schools may be destroyed and a large, consolidated school established. In communities where the school is a major economic, political, or social factor, the destruction of inadequate schools will occur at a very slow rate. Often, in such cases, a school must be destroyed by "outside" agencies and consolidation with other schools forced upon it.

An improbable event may be introduced into a school and may persist. At the turn of the century, the building of playgrounds and athletic facilities in schools was highly improbable. Most physical education facilities were established outside of schools. At present a considerable portion of every school budget is allocated to physical education, and it has taken on the form of interscholastic competition. In the form of interscholastic competition it persists, and even is a factor in the persistence of a school. Consolidation is opposed, because the home town does not want to lose its team.

If a subsystem does not exchange parts with another subsystem, an improbable event can exist in one subsystem and not in the other. The existence of a non-church going person in the teaching unit of a church-related school which requires church going persons in the administrating unit, because there is no exchange in persons between the two units, is an illustration. The environment of the teaching unit differs enough from the environment of the administrating unit; so that the non-church going person can exist in the teaching unit, but could not if introduced into the administrating unit.

In most schools, staff vacancies cannot be filled through "inbreeding." Feedback of graduates will not sufficiently regulate school action. Personnel recruited from other communities and other states are most often employed in the teaching and inquiring units. Less frequently, such recruitment occurs in administrative units. Such formation and reformation of school subsystems, therefore, results in irregularities. Such irregularities subject schools to change.

Randomness: The conditions for change in a school and in its environment introduces randomness in its operations. Randomness appears to be a function of school size and the number of different social units in a school's environment. School stability is an inverse function of randomness.

Actions of a School

Nucleus for School Growth: It appears that the minimum elements from which a school can develop is one person as a teacher and one person as a student. Usually, the nucleus of a school consists of a board of control, at least one teacher, and more than one student. Harvard College had such beginnings. The persons who formed the nucleus of Harvard College were homogeneous; all were Congregationalists. As Harvard College grew to Harvard University, it became a system which was in no way homogeneous to its nucleus. The constituents of its Board of Overseers changed from church elders to businessmen; the college presidents' professions changed from theologian to academician; and the student body changed from scions of leading Congregationalist families in Massachusetts to a heterogeneous group representing different geographical localities, classes, and beliefs.

Carpenter Principle: In a school that has rigorous specifications for each detail of development of each unit, there must be a high degree of organization to produce the adjustment necessary. It would be unlikely that initial selection of persons, things, etc. could secure the fitting required by such planning. A school whose development requires carpentering is restricted in growth possibility. Growth in military academies, technical schools, and certain sectarian schools follows the Carpenter Principle. As a consequence, these schools will not produce the number and varieties of personalities, role takers, structured information, and commodities produced by other schools having the same population base. With other factors equal, the diversity within the output of a school may function as a predictor of size of school growth.

Although all schools which grow according to the Carpenter Principle are highly organized, a school which does not so grow can become highly organized through centralization. As noted previously, progressive systemization may occur in a decentralized school. Regardless of the process by which a school becomes centralized, such a school will contain fewer growing edges than a decentralized school, and its rate and size of growth will have lower limits than a decentralized school.

Exponential Growth: If resource input is not below some limit, the path of a school's growth until some maximum size is obtained will be characterized by an exponential curve. Beyond that maximum, growth may cease or branch schools may be established. Generally, exponential growth in schools is manifested by rapid increase in rate of growth through a given period of time.

Proportionality and Growth: For a school to grow, the relative size of the units cannot remain constant. Yet if there is no compensation for the non-proportionality due to growth, the school will eventually degenerate. Growth will lead to death, if it is cancerous. One or more units will lose their identity due to the overwhelming development of one or more other units. The development of the administrating unit at the expense of the other units of a school is a frequently observed phenomenon.

D'Arcy Thomson Principle: The principle that the form of an entity is a result of the laws of growth up to that moment is applicable to the school, particularly in regard to its physical form. The growth of buildings requiring natural light and ventilation will tend to increase more rapidly in length and height than in breadth. First, wings and courts will be added. If structurally possible, later growth will result in increase in height. Further growth may result in increase in breadth, with the inclusion of more extensive artificial light and ventilation in rooms and sections which do not have an outside wall. School buildings which employ only artificial light and ventilation will tend to be oval or cubical in shape, and will grow in volume rather than in area. Such buildings will show less convoluted growth than buildings using principally natural light and ventilation.

Principles of Equal Advantage and Demand: In a school, the principle of equal advantage and the principle of demand operate. Where the teaching unit of a given school contains many students within one kind of curriculum and fewer in another kind of curriculum, it will be the latter students who will have greater educational advantage. What will happen then will be more enrollment of students in the curriculum in which fewer students are enrolled.

A decentralized school will tend to grow according to these principles. For example, a university will favor a location for a branch campus where the demand for enrollment is high, and where the demand exceeds the capacity of schools already established in that location.

Pinocchio Principle: The tendency for the subsystems of a school to tend toward independence is particularly marked in a decentralized school. Branch campuses established by a university tend to become completely independent.

Efficiency: Schools will perform at an efficiency for maximum power output which is always less than maximum efficiency. For example, a school may operate two shifts under peak loads. If a school is not able to increase financial resource, it will continue on a two-shift basis while attempting to raise the necessary funds. Even though a school functions on a two-shift basis, there are other means available for absorbing even greater student enrollments. A school may increase the size of sections and reduce the number of elective curricular offerings, or introduce instruments such as television for mass instruction.

Regardless of school efficiency, there is always less output than there is input, i.e. schools do not operate at 100% efficiency. Not all students who enter a school are graduated. Not all knowledge available for instruction is processed. Not all demands for educational programs are met.

Alteration: The input of a school is characteristically altered. The persons graduating from a school will tend to bear the "stamp" of the school. Alteration may or may not be apparent readily in the behavior of school graduates. For example, it always may not be easy to identify a Harvard man in a business office, but a West Pointer in the Army is unmistakable.

Alteration in a school is the sum of the effects of subsystem operations which subtract from its input and add to its output. Any elementary school in the United States, for instance, will instruct its students in cleanliness. "Non-hygienic habits" of children will be given attention in an effort to remove them and replace them with "hygienic habits." This addition of "hygienic habits" may involve home visits by school personnel or by representatives of social agencies receiving school referrals.

Alteration of input by a school in its output involves interaction of the output wanted by the community and that wanted by school personnel. It also involves the nature of environmental conditions and the characteristics of student input. An elementary school in a disorganized community (e.g. in a metropolitan slum area) may realize little alteration, although operations in the school are directed to alter its input. Such considerations suggest that realized alteration in relation to school goals might provide a measure of school efficiency.

Amount of Input: If input is high, a school may omit some of that input. To illustrate, an elementary school with high enrollment demands may require strict adherence to age requirements in relation to entrance. A college or university may raise its entrance requirements, or promulgate information relating high school achievement to successful college learning.

Another way a school can meet high input is by filtering it. The school responds to only certain demands or establishes a priority list. In a public secondary school, individual curricular demands are often spilled; but not those from organized groups.

A school will ignore or cut off input that is excessive. If student enrollment approaches school capacity, the school will ignore requests for enrollment. If requests cannot be ignored, the school will try to send students to other schools not burdened with excessive enrollment.

Fluctuating school input results in storage of input during peak loads and catching up during lulls. Under fluctuating enrollment demands, a school might store students by requiring certain students to enroll during terms with low enrollment.

Under high input, a school's output will be less precise. In a school where financial resources restrict school growth and student input cannot be spilled or filtered, students will be advanced to higher levels of instruction, although they do not meet standards for advancement. Under such conditions, school reports become less detailed and less frequent.

If input into a school continues to increase, stress will be produced. Stress can be met by progressive segregation, provided the stress does not continue. To process over-capacity enrollment, a school may use other buildings in the community or erect temporary structures until new buildings become available. Through such progressive segregation, the instability due to the stress from enrollment increase is reduced. If the stress continues, continuing progressive segregation can lead only to increasing independence, which in itself produces instability.

A centralized school under stress requires more effort to maintain stability than a decentralized system. In a system which is decentralized, regulatory processes do not limit the independent action of subsystems as much as they do in a centralized school. Thus, instability in one subsystem can be reacted to with less concomitant action in other subsystems. High input in a one-room school--the most highly centralized--results in instability more rapidly than in any multi-room school. The centralized school, however, under no stress is more stable than a decentralized school. A one-room school in a highly organized community with a slow rate of population growth is subject to gradual change in input. As a consequence, change in input does not require extensive or rapid change in school action. A measure of such stability in a one-room school might be obtained by calculating its rate of personnel turnover.

In reducing stress, a school will first use the least effort, and then increasingly greater effort. For example, under rapid enrollment increase, teachers may be required to work with more students. If the enrollment is above normal capacity, the school day may be divided into two shifts and "free" time in school of students and staff will be lessened. If the enrollment does not fall to previous levels, new facilities and personnel may be acquired.

Feedback and Degeneration: Regulatory processes in a school function to establish equivalence of input with output. Without feedback of school output, the property of independence will increase until the school degenerates. To illustrate, with no evaluation of the the produced personalities, role takers, structured information, and commodities, the administrating unit could not establish policies relating this output to the wanted personalities, role takers, structured information, and commodities. Disjunction between wanted output and produced output would result in disjunctive policies effecting actions of the other subsystems. In time, relationships between all subsystems would disintegrate and the school would collapse.

Output Transmission: Change in school output requires greater effort to produce than change in subsystem outputs. Such action is illustrated by the time and effort required to include a new wanted personality, role taker, structured information, or commodity in school output as compared to the effort and time required to introduce a new instructional device--television teaching--in a teaching unit.

SIGNIFICANCE OF THE EDUCATIONAL THEORY MODEL

Little needs to be written on the significance of General Systems Theory for the behavioral or social sciences. Each of the six yearbooks of the Society for General Systems Research reports a growing interest in the theory as a point of view for theorizing about the behavior of individuals and social organizations. The election of Ludwig von Bertalanffy, Charles A. McCelland, and Kenneth E. Boulding as presidents of that Society suggest the reach of the theory, for the interests of these men are biology, history, and economics respectively.

Before this paper, General Systems Theory has had little explicit significance for educational theory. Present and past references to school systems and organismic descriptions of schools in most texts on education suggest implicit use of system concepts in developing concepts to account for school events. Explicit use of General Systems Theory has been by Griffiths (7), Gordon (8), Clifton and Smith (9), and Thompson (10). Griffiths indicated one could employ an open system model to devise administrative theory. In setting forth newly developed concepts in the behavioral sciences and their implications for educational theory, Gordon included some generalizations based upon General Systems Theory. Clifton and Smith studied the use of motion pictures as a means for providing feedback of performance to a student. Thompson viewed ideologies in educational research and practice as "self-sustaining" systems.

After this paper, General Systems Theory should be seen as having explicit significance for educational theory. Although the theory generated from the model, General Systems Theory, is little more than an outline of an educational theory, its prima facie power for explaining the school and its actions attests to the significance of the model for educational theory. The educational theory appears to have common-sense relevance. That it has fruitfulness is apparent, because generalizations in the theory can be stated as hypotheses which can be empirically tested and which, for the most part, as the survey to follow will indicate, have not been tested.

Turning from face value observations on the relevance of the theory, it can be shown through the literature that descriptions of actual school organization and practice suggest further relevance of the outlined educational theory. Since the focus in this paper was on the construction of a significant educational theory model and not on the educational theory itself, no exhaustive review of literature was conducted. The review of literature for relevancy was restricted to some reports of school organization and school action. Proposed and theoretical organizations and actions were not included.

In all references to be cited, the school was viewed implicitly as an open system. Discussion of practice was in terms of incoming and outgoing events. Throop, in reporting a plan for the development of more realistic attendance boundaries and transportation boundaries, characterized these boundaries as dynamic and as extending beyond the actual school site. (11)

In their organizational chart for Ballard High School, Seattle, Washington, Van Devanter and Seeley, indicate input-output relationships between teachers and the administrating unit. Their diagram also suggests the inclusion of teaching personnel within the administrating unit. (12) Relationships between facilitating and teaching units are indicated by Chewning. He reported an architectural oversight which limited teaching of physics. (13) Raub's study provides a detailed description of the inquiring service performed by the public schools of Amsterdam, N.Y. The school was instrumental in helping the community repair the economic injury caused by the loss of major industries located in the community. (14) The reports of Van Devanter and Seeley, Chewning, and Raub point to the relevance of the four subsystems (administrating, facilitating, teaching, and inquiring) which were specified in the educational theory derived from General Systems Theory. These studies also suggested connecting relationships between these subsystems and their effect on the output of the subsystems or the school.

Chewning also reports an extension of school resource input through the Engineering Club of Durham which agreed to provide funds and technical assistance for needed laboratory apparatus in the school.

Regulatory processes between the administrating and teaching unit are illustrated in the Ballard High School Organizational Chart. Personnel in the teaching and administrating units overlap. The inclusion of some teaching personnel in the administrating unit appears to provide immediate feedback of the output of both units, and direct communication between the two subsystems. Chewning's experiment makes apparent the result of feedback of a facilitating unit's output (a new building). The Engineering Club of Durham undertook to correct the oversight in laboratory resource. The employment of regulatory process for maintaining high level of teaching in the teaching unit is described by Marvin Garlich. Professional growth points were established by a committee of four teachers elected by their peers and two administrators elected by their peers. This committee was authorized to evaluate self-submitted growth plans of teachers, hear appeals of teachers, and to draft recommendations for submission to the superintendent. The superintendent held veto power over recommendations. (15)

Raub's study provides an actual example of school action through which wanted occupational roles in school input are identified and produced in school output.

Both the Ballard High School administrative organization and the organization at the Alonzo Aldrich Junior High School (16) show that these schools are ordered hierarchically and centralized in the administrative unit. Hierarchical order is pointed to in Garlich's study on professional growth. The Ballard High School administrative structure indicates that this school is highly organized. Virtually every relationship of the teaching unit to the administrating unit is delineated.

Judging from the reports reviewed, much administrative action in schools relates to the maintenance of school stability, and to anticipation of changes required by increased enrollment. Martin's report on a plan for "opening the school year successfully" is relevant to the proposition that a school is a steady-state system. He sets forth a plan intended to reduce instability through workshops for administrative staff, new teachers, and other professional staff held just prior to school opening. The conclusion is that the quality of opening appears proportional to the pre-opening planning. (17)

The theory suggests that changes in subsystems which exceed certain limits effect stability within a school. Hays reported that releasing teachers from custodial duties did not result in serious disciplinary problems, and that more teaching occurred in the teaching unit. This change led to "more productive teaching." Although not reported in terms of stability, his study suggests that such action has effects on school stability. The Hays Study also indicates wholeness resulting from change in a subsystem of a school. The introduction of lay supervisors resulted in training of lay supervisors, reapportioning the budget, recruitment of lay supervisors, and defining their status as that of other nonprofessional employees under the principal's supervision. Change in action of the teaching unit was recorded also. Teachers spent their released time in remedial teaching and in planning. (18)

Doherty commented on the problem resulting from the employment of marginal teachers who were placed on tenure and who suffered deterioration of performance becoming less than satisfactory. He set forth a remedial program for such teachers and a requirement that these teachers undertake the program or be released by the Board. (19) Doherty's study suggests the relevance of the proposition that, for stability, change in subsystems of a school remains within certain limits.

A study by Reed illustrates catching up through processing input during lulls. She conducted remedial reading programs during the summer. (20) Chamberlain discussed "five steps to predicting future teacher need." (21) The steps illustrate relevance of the theory in relation to maintaining limits of variability within subsystems, and spilling and filtering of input under conditions of increasing enrollment.

Throop's study, referred to above, illustrates the use of the Principles of Demand and Equal Advantage in determining the number and location of future schools.

Surely on the basis of even such a brief review the significance of the model has been underlined. The educational theory, therefore, merits further development.

FOOTNOTES

(1) Ludwig von Bertalanffy, "General System Theory," in Main Currents in Modern Thought, Vol. 71, 1955.

(2) James G. Miller, "Toward a General Theory for the Behavioral Sciences," in The American Psychologist, Vol. 10, September 1955.

(3) James G. Miller, "Information Overload," in Self-Organizing Systems, ed. by M. C. Yovits, Washington, D.C.: Spartan Books Inc., 1962.

(4) A. D. Hall and R. E. Fagen, "Definition of a System," in General Systems, Vol. 1, 1956.

(5) K. E. Boulding, "Toward a General Theory of Growth," in General Systems, Vol. 1, 1956.

(6) J. W. S. Pringle, "On the Parallel Between Learning and Evolution," in General Systems, Vol. 1, 1956.

(7) Daniel E. Griffiths, "Some Assumptions Underlying the Use of Models in Research," in Research and Educational Administration, ed. by Stephen F. Hencley, Cooperative Research Project F2, 1962, pp. 43-59.

(8) Ira J. Gordon, "Developments in Human Behavior," in Educational Theory, Vol. 8, No. 4, 1959, pp. 259-268.

(9) Marguerite A. Clifton and Hope M. Smith, "Viewing Oneself Performing Selected Motor Skills in Motion Pictures and Its Effects upon Expressed Concept of Self in Performance," in Research Quarterly, Vol. 33, No. 3, 1962, pp. 369-375.

(10) John W. Thompson, "Method Ideology and Educational Ideologies," in Educational Theory, Vol. 12, No. 2, 1962, pp. 110-116.

(11) Harold L. Throop, "Simplifying Student Population Projection," in American School Board Journal, Vol. 145, No. 1, 1962, pp. 11-12.

(12) A. D. Van Devanter and Frank E. Seeley, "An Administrative Model for a Large City High School," in National Association of Secondary School Principals Bulletin, Vol. 46, No. 275, 1962, pp. 99-102.

(13) Charles H. Chewning, "An Experiment in Upgrading High School Physics," in American School Board Journal, Vol. 144, No. 5, 1962, p. 5.

(14) Stanley L. Raub, "Adult Education and the Industrial Process," in American School Board Journal, Vol. 144, No. 6, 1962, p. 21.

(15) Marvin D. Garlich, "A Balanced Teacher Compensation and Growth Plan," in American School Board Journal, Vol. 145, No. 2, 1962, pp. 9-10.

(16) Marvin D. Garlich, "Alonzo Aldrich Junior High School," in American School Board Journal, Vol. 144, No. 2, 1962, pp. 24-27.

(17) Robert P. Martin, "Opening the School Year Successfully," in American School Board Journal, Vol. 145, No. 1, 1962, p. 19.

(18) R. Vernon Hays, "Lay Supervisors for Lunch Hours," in American School Board Journal, Vol. 144, No. 3, 1962.

(19) Victor A. Doherty, "A Solution to One Problem Created by Tenure," in American School Board Journal, Vol. 144, No. 4, 1962, p. 20.

(20) Estella Reed, "Using the Summer for Remedial Reading," in American School Board Journal, Vol. 144, No. 5, 1962, p. 18.

(21) Leslie J. Chamberlin, "Five Steps to Predicting Future Teacher Need," in American School Board Journal, Vol. 144, No. 2, 1962, pp. 16-17.

AN EDUCATIONAL THEORY MODEL: AGRICULTURAL ECONOMIC THEORY*

by Robert E. Jewett

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Introduction

The industrial economy frequently has been used as a model to generate educational theory. Efficiency of production in industry and in the educational system has been compared. Personnel relationship and personnel management within the two systems have been compared. The type and method of innovation, the process of social change in the two systems have been the subject of comparison and contrast.

The agricultural economy, however, has been used with much less frequency as a model for generating educational theory. Yet, in the writer's opinion, this agricultural economy is a much more fruitful model for application to the educational system than is the industrial economy. In the following paragraphs the writer will indicate the reasons for his opinion.

In the agricultural economy and in the educational system, in contrast to the industrial economy, the raw material actively enters into the process of production. Plants and animals, and students, in contrast to the raw material of manufacturing, interact with the efforts of the producer. The farmer and the teacher, in contrast to the manufacturer, must reckon with the physiology of the raw material. Thus the former two producers, unlike the latter one, lack complete control over the productive process due to the nature of the raw material.

Furthermore, the individual raw material within the agricultural economy and within the educational system, in contrast to the manufacturing economy, vary greatly in their productive capacity. Both individual plants and livestock, and individual students vary in their productive capacity.

In the agricultural economy and in the educational system, but not in the manufacturing economy, the producer encounters the factor of maturation in raw material. Both the farmer and the teacher are concerned with the developmental transformation of the raw material. In both cases the nature of the raw material sets limits to the rate of the productive process.

The productivity both of the farmer and the teacher, in contrast to the manufacturer, is subject to factors beyond the control of the producer. The farmer's productivity to a large degree is subject to conditions of rainfall, temperature, and other weather conditions. Climatic conditions limit the farmer's productivity. Similarily with the teacher, the social climate of the society in which the school exists limits the productivity of the teacher.

For the reasons given above the agricultural economy rather than the industrial economy will serve as the model for generating educational theory in this paper.

Designation of equivalent terms

In describing features of the agricultural economy model, terms will be used for which equivalent terms will be employed in describing corresponding features of the educational system. Therefore, the reader is provided a comparative listing of such terms below.

Agricultural Economy Model		Educational System
plants and livestock	↔ raw material ↔	pupils (students)
food		content
livestock products		pupil understanding, pupil knowledge, skills
farmer		teacher, professor
production goals		educational purposes
livestock care		nurture of pupils
agricultural methods		educational methods

The agricultural economy model

The model consists of an agricultural economy. Included in the model are two types of such economies: one a subsistence economy, and one a market economy.

The agricultural subsistence economy has the following features.

(1) The farmer is a generalist. He does not specialize in the production of a single crop or type of livestock. Rather he produces the variety of crops and livestock necessary for his family's livelihood.

(2) The goals of production are determined by the farmer.

(a) The quantity to be produced is determined by the farmer.

(b) The type and quality to be produced is determined by the farmer.

(3) The farm economy is based upon a lack of exportable surplus. All that is produced is consumed on the farm--nothing is put on the market. The farmer and his family frequently experience scarcity after having consumed the total productivity of the farm.

(4) The nature of the care given the livestock is determined by the farmer.

(5) The selection of food and the quantities of food afforded the livestock is determined by the farmer.

(6) The produce of the farm must provide for the economic needs of the farm family. The farm family is economically self-sufficient.

(7) The welfare and productivity of the livestock is dependent on the skill and industry of the farmer.

(8) Combining (6) and (7) above, a type of symbiotic relationship emerges between the farmer and the livestock. The livestock provides products for the farmer's livelihood and the farmer provides the care and food necessary to maintain the welfare of the livestock.

(9) The farmer knows and evaluates each farm animal on the basis of a wide range of characteristics. The farmer knows the habits, the behavior, and the productive capacity of each animal. He evaluates each animal on the basis of the total behavior of the animal, not solely in terms of productive capacity.

(10) The farmer has little incentive to produce a supply of food in excess of the needs of his livestock and his family. Since he is not producing for the market he has no outlet for surplus food.

(11) The farmer has little incentive to produce livestock products in excess of the needs of his family. Living in a subsistence economy he has no outlet for excess livestock products. Conversely, all that he produces is needed to maintain his family who cannot rely on the market to fulfill their economic needs.

(12) The farmer has neither the facilities nor the incentive to produce new types of food for his livestock. He must rely on outside agencies whose purposes and facilities are geared for such activities to supply him with new and improved types of livestock food.

(13) The farmer feeds the type and guantity of food to his livestock that will result in maximum welfare for the livestock. The farmer does not "force feed" for market product. He does not feed to produce a particular speciality for the market (i.e. lean meat).

(14) The farmer tends to retain and care for livestock that are inefficient producers. In contrast to the farmer producing within a market economy, he is less conscious of the economic worth of the livestock and more identified with the total worth of individual animals.

(15) The type of livestock food which the farmer produces is determined by the needs of his livestock. He has no incentive to produce food which is not suitable for consumption by his particular livestock. He has no economic outlet for such production.

(16) The farmer values his productive efforts as a way of life. He attributes moral and spiritual values to his farming activities. Farming, as he views it, builds character. He is performing an essential function.

(17) The farmer is distrustful of those farmers engaged in production for a market economy. He has little in common with them. He finds it difficult to communicate with them. He identifies them with the business world while he thinks of himself as less commercially motivated.

(18) Other subsistent farmers in judging the worth of the farmer place emphasis on the quality of the farmer's care of his livestock.

(19) The farmer has a community of interest with other subsistent farmers. He finds it easy to communicate with them.

The agricultural market economy has the following features.

(1) The farmer is a specialist. He concentrates his productive effort in the growing of particular crops or the feeding of particular types of livestock. He specializes in this manner in order to produce for the market.

(2) The goals of production in the long run are determined by the demands of the market.

(a) The quantity to be produced in the long run is determined by the demands of the market.

(b) The type and quality to be produced in the long run is determined by the demands of the market.

(3) The farm economy is based on surplus production. More is produced than the farmer and his family can consume. The surplus production is placed on the market.

(4) The nature and amount of the care which the farmer gives the livestock is determined by its cash value in the market. That is to say that the farmer determines the amount and type of care he gives his livestock on the basis of producing the maximum cash returns from the product of the livestock. He does not give care to the livestock beyond the point where it is economically profitable.

(5) The selection of the type of food and the amount of food which the farmer affords his livestock are determined by the demands of the market for livestock products. Aesthetic or humane considerations do not enter into the decision.

(6) The surplus of products of the farm brings the farmer a cash return on the market.

(7) The farmer evaluates the worth of each farm animal on the basis of the market value of its products. Non-economic characteristics of the animal are not considered. The farmer culls out and disposes of all livestock which fails to produce a profit on the market.

(8) The farmer produces livestock food in accordance with the demands of the market.

(9) The farmer produces livestock products in accordance with the demands of the market.

(10) The farmer is forced to introduce new, improved methods of farming as soon as they become available in order to meet the competition of the market.

(11) The farmer is forced to introduce new, improved livestock foods as soon as they become available in order to meet the competition of the market.

(12) The farmer is forced to introduce new, improved varieties of livestock as soon as they become available in order to meet the competition of the market.

(13) The farmer learns of new farming methods, new livestock foods, and new varieties of livestock by keeping in contact with other farmers in his particular speciality. He accomplishes this by attending meetings and by reading journals devoted to his particular speciality.

(14) The farmer values his ability to produce a surplus for the market and the way of life which this surplus makes possible.

(15) The farmer is somewhat contemptuous of the subsistence farmer. The former has little in common with the latter.

(16) The farmer has little in common with other market economy farmers whose speciality is different from his. He finds it difficult to communicate with them.

Within the overall framework of the agricultural economy model, the subsistence economy and the market economy have the following characteristics in common.

(1) Livestock that are efficient in converting food into livestock products are prized by the farmer.

(2) The quantity, type, and quality of the food which the farmer feeds his livestock are vital factors in determining the productivity of his livestock.

(3) There is a wide range of individual differences in the ability of livestock to convert food into livestock products.

(4) Livestock may reject the food which the farmer provides.

(5) Livestock may consume the food which the farmer provides but fail to digest it.

- (a) The undigested food may be retained within the body of the livestock causing a lowering in the efficiency of the livestock's productivity.
- (b) The undigested food may be expelled by the livestock. In which case the overall productive efficiency of the livestock is not impaired but the animal does not convert the food in question into animal products.

(6) Livestock may digest the food thus converting it into livestock products.

(7) Factors beyond the control of the farmer such as climate and rainfall have a decisive effect on agricultural productivity.

(8) The process of maturation in livestock is an important factor in determining the nature and rate of livestock productivity.

(9) Historically, the trend in the agricultural economy has been in the direction of an extension of the market economy at the expense of the subsistence economy. There has been an increasing amount of specialization and an increasing variety of specializations. There has been an increasing proportion of farmers producing for the market and a corresponding decreasing proportion operating within a subsistence economy.

Educational theory

The consideration of educational theory in this paper will be confined to the educational process as carried on within the formal school system. No attempt will be made to examine the educational process as it operates in the whole of society. The institution of the school alone will be considered below. For purposes of analysis attention will be centered on two distinct types of schools: the elementary school, and the university.

The elementary school whose characteristics are described below is one which is not organized along departmental lines. The assumption is made that the primary function of the elementary school is to promote general education.

This type of elementary school has the following features.

(1) The teacher is a generalist. He does not center his efforts on producing within his pupils understanding and skills within a particular discipline to the exclusion of attention to other disciplines. His background, his competencies, and his commitment is such as to direct him to a consideration of the whole child. He is attempting to produce a general education for the pupil, not a specialized or vocational education.

(2) The purposes of education are determined by the teacher. Since the teacher is promoting general education rather than specialized education, the demands of the job market do not determine educational purpose. The teacher determines the goals of general education, of course, within the limits set by the norms of the society.

- (a) The quantity of learning desired is determined by the teacher.
- (b) The type and quality of learning to be achieved is determined by the teacher.

(3) The elementary school does not produce within the pupil specialized knowledge and skills which can be utilized on the labor market.

(4) The nature of the nurture given the pupils is determined by the teacher.

(5) The selection of types of content and the quantities of content afforded the pupils is determined by the teacher.

(6) The knowledge and skills acquired by the pupils justifies the existence of the elementary school. The personal-social development of the pupil through general education, not the acquisition of marketable skills through specialized education, places the elementary school in a unique and essential role in society.

(7) The productivity of the pupil is dependent on the teacher's skill and the nature of the individual pupil.

(8) Combining (6) and (7) above we arrive at a type of symbiotic relationship between the pupil and the elementary school. The self-development of the pupil justifies the existence of the elementary school. The pupils are dependent on the school for this development.

(9) The teacher knows and evaluates each pupil on the basis of a wide range of the pupil's characteristics. The teacher knows the habits, the behavior, and the intellectual capacity of each pupil. He evaluates each pupil on the basis of the total behavior of the pupil, not solely in terms of intellectual capacity.

(10) The teacher has little incentive to gain command of content in excess of the needs of his pupils.

(11) The teacher has little incentive to teach skills and knowledge appropriate for vocation. He is not preparing pupils directly for the job market. He is not in the business of developing salable skills. All of the understandings which he develops in his pupils are used by the pupils in becoming a person.

(12) The teacher has neither the incentive nor the facilities to carry on the scholarly research necessary to produce new content for his pupils. He must rely on the university and other centers of scholarly research whose purposes and facilities are geared for such activities.

(13) The teacher provides his pupils with the type of content designed to further their general education. He does not select content for his pupils of the type that will promote vocational training. He does not "press" content upon them to promote intellectual development at the expense of emotional and physical development.

(14) The teacher accepts and attempts to bring about the maximum general development of all pupils. He does not reject the slow learner. He is oriented to citizenship education and self-development for his pupils not specialized education for vocational ends. Therefore, he is interested in the general education of all pupils.

(15) The type of content which the teacher acquires is that which has meaning for his pupils within the context of general education.

(16) The teacher values his teaching career as a way of life. He views teaching as a profession.

(17) The teacher tends to have few common interests with the university professor who is engaged in educating students for a vocation or a profession. He tends to believe that the professor is not sufficiently sensitive to the overall development of students and that the professor is too concerned with specialized education.

(18) Other teachers in the elementary school in judging the worth of the teacher, place emphasis on the quality of the teacher's care of his pupils.

(19) The teacher has a community of interests with other elementary teachers. He finds it easy to communicate with them.

The instructional activities of the university designed to educate for a vocation or profession along with the pre-vocational and pre-professional education designed to prepare for vocational or professional education will be the phase of the university under examination. The writer will not be concerned with the general education aspects of the university education.

The special education phase of the university has the following characteristics:

(1) The teacher is a specialist. He carries on research in a particular scholarly discipline. He educates students for particular vocations or professions.

(2) The purposes of specialized education in the long run are determined by the demands of the outside world of work--by the labor market.

- (a) The quantity of each vocation and profession in the long run is determined by the demands of the labor market.
- (b) The type and quality of persons to be produced in the long run is determined by the demands of the labor market.

(3) The university is characterized by surplus production of content.

- (a) Through research, the professor produces more content than his students can master.
- (b) Through publication, the professor places his findings on the market.

(4) The professor's concern for his students, as students, is confined to developing within them the capacity to carry out the functions of the particular vocation or profession.

(5) The professor's selection of type of content and the quantity of content is provided the students by societal demands for particular qualities in the persons practicing the vocation or profession.

(6) The surplus of content produced in the university brings rewards to:

(a) the university in the form of prestige,

(b) the individual professor in the form of professional advancement.

(7) The professor evaluates each student on the basis of his ability to acquire the knowledge and skills essential in the vocation or profession for which the student is being educated. The professor screens out of the college those students he deems to be unfit for the particular vocation.

(8) The professor tends to do the type of research for which there is a market--the type which will find a publisher.

(9) The professor educates students for those vocations or professions for which there is a demand on the labor market.

(10) The professor is influenced to introduce new teaching methods when these new methods are more efficient in educating students for particular vocations or professions.

(11) The professor is influenced to introduce new content in vocational education when the demands for particular vocational knowledge and skills change on the labor market.

(12) The professor learns of new research in findings in his area of specialization by keeping in contact with other professors in his area of specialization. He does this by attending conferences and by reading journals devoted to his particular speciality.

(13) The professor values his ability to do scholarly research and to publish it. He values the way of life which this ability makes possible.

(14) The professor has little in common with the elementary teacher.

(15) The professor has little in common with professors who have other specialties. He finds it difficult to communicate with them. He works and communicates largely with professors whose speciality is the same as his.

Within the overall framework of the educational system, the undepartmentalized elementary school and the specialized aspects of the university have the following characteristics in common.

(1) Students that evidence marked ability to convert content into understandings are prized by the teacher.

(2) The quantity, type, and quality of content which the teacher affords his students are vital factors in determining the quality and quantity of learning which his pupils achieve.

(3) There is a wide range of individual difference in the ability of students to convert content into understandings.

(4) Students may reject content provided by the teacher.

(5) Students may "take on" the content but not convert it into understandings.

- (a) The content may be retained by the student as inert facts causing a lowering of the ability of the students to achieve understandings.
- (b) The unconverted content may be forgotten. In which case the overall ability of the student to learn is not impaired but the student does not convert the content in question into understanding.

(6) Pupils may convert the content into understandings.

(7) Factors beyond the control of the teacher such as the general social climate in the wider culture have a decisive effect on teaching effectiveness.

(8) The process of maturation in students is an important factor in determining the nature and rate of student learning.

(9) Historically, the trend in the educational system has been an extension of specialized (vocational, professional) education at the expense of general education. There has been an increasingly greater amount of specialization and an increasingly greater variety of specializations. This trend has reached "down" into the upper levels of the elementary school. At the university level there has been an increasing interest in specialization and publication and possibly a decreasing effort to provide general education.

Significance of the model

The preliminary treatment of the educational theory provided in the above section of this paper possibly offers the most satisfactory basis for judging the significance of the model for generating educational theory. Furthermore, many of the propositions listed in the section on educational theory, at least in their present form, are expressions of common sense. Such statements do not lend themselves to documentation from the literature. Hence, the citations of literature appearing below are quite fragmentary and quite general in their application to the theory developed as illustrative of the possibilities of the model.

Harold Shane in discussing the objectives of the elementary school, points to a tendency to place greater emphasis on the intellectual development of the pupil. (1) This emphasis of necessity leads to greater specialization on the part of the elementary teacher. Many other authorities in the area of elementary education have noted the same trend in recent years.

In the book, Education in Social and Cultural Prospective the author clearly delineates the nature and the roles of general and special education as they function in our present school system. (2) The author points up many of the propositions listed in the above section on educational theory.

P. R. Trumpler in an article entitled, "American Universities and Federal Research," recognizes the relationship of publication to the market economy. (3) C. P. Smith makes much the same point in an article entitled, "Teaching, Research, and Publication." He emphasizes the rewards occurring to the professor in the form of prestige and academic advancement from writing that is accepted in the market place. (4)

Data appearing in the International Yearbook of Education (5) substantiate the trend in the direction of a greater degree of specialization in institutions of higher learning both within the United States and throughout most of the rest of the world. This source not only indicates a greater emphasis on specialization but it also points to a greater proliferation of specialization.

Many of the propositions stated in the section of this paper relevant to the role of the professor in specialized education are very well treated in The Academic Mind by Paul F. Lazarsfeld and Wagner Thielens, Jr. (6) They clearly show the relationship between the professor's role and the general culture. Included in their analysis is a recognition of the impact of publication on the status of the professor.

The forces operating in the culture to extend specialized education at the expense of general education are analyzed by H. A. Tonne. (7) Also W. W. Brickman in an article entitled, "Research, Scholarship, and Teaching in the University" stresses the need for specialization in scholarship and research. (8)

In an article entitled "Students' Views Regarding General Education," P. L. Dressel points out that students, influenced by social pressures, want the universities to emphasize specialized education. (9) Thomas R. Ford makes much the same point. (10)

Donald R. Harkness questions the appropriateness of general education in a world in which students are emphasizing the cash value of an education. (11) Jack Stewart in an article entitled, "Schools Didn't Give Us What We Wanted" reports that the students interviewed wanted more specialized education. (12) M. Ray Thomas reached a similar conclusion. (13)

The above review of the literature points to the relevance of the theory, and so the significance of agricultural economic theory as a model.

FOOTNOTES

(1) Harold Shane, "Elementary Education-Objectives," in N.E.A. Journal, Vol. 51, No. 6, September 1962.

(2) Harold L. Hodgkinson, Education in Social and Cultural Prospective, Prentice-Hall Inc., 1958.

(3) P. R. Trumpler, "American Universities and Federal Research," in Journal of English Education, April 1961.

(4) C. P. Smith, "Teaching, Research, and Publication," in Journal of Higher Education, Vol. 32, April 1961.

(5) International Yearbook of Education, Vol. 22, 1961.

(6) Paul F. Lazarsfeld and Wagner Thielens, Jr., The Academic Mind, The Free Press, 1958.

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AN EDUCATIONAL THEORY MODEL: PHARMACOLOGY AND PHARMACOGENETICS*

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"Well, I should like to be a *little* larger, Sir, if you wouldn't mind," said Alice: "three inches is such a wretched height to be."

. . . .

. . . Alice waited patiently until it chose to speak again. In a minute or two the Caterpillar took the hookah out of its mouth, and yawned once or twice, and shook itself. Then it got down off the mushroom, and crawled away into the grass, merely remarking, as it went, "One side will make you grow taller, and the other side will make you grow shorter."

. . . .

Alice remained looking thoughtfully at the mushroom for a minute, trying to make out which were the two sides of it; and, as it was perfectly round, she found this a very difficult question. However, at last she stretched her arms round it as far as they would go, and broke off a bit of the edge with each hand.

"And now which is which?" she said to herself, and nibbled a little of the right-hand bit to try the effect. The next moment she felt a violent blow underneath her chin: it had struck her foot! . . . Her chin was pressed so closely against her foot, that there was hardly room to open her mouth; but she did it at last, and managed to swallow a morsel of the left-hand bit.

"Come, my head's free at last!" said Alice in a tone of delight, which changed into alarm in another moment, when she found that her shoulders were nowhere to be found: all she could see, when she looked down, was an immense length of neck . . . .

. . . .

After a while she remembered that she still held the pieces of mushroom in her hands, and she set to work very carefully, nibbling first at one and then at the other, and growing sometimes taller, and sometimes shorter, until she had succeeded in bringing herself down to her usual height.

I. INTRODUCTION

As Alice, others desire to eliminate what they take to be their wretchedness. So remedies are sought. The patient takes his wretchedness to a doctor, and the student takes his wretchedness to a teacher. But the doctor must know the remedies, as must the teacher. The doctor must rely upon studies of effects among which is pharmacology--the study of the effect of drugs, and the teacher must rely upon the study of the effect of teaching--pedagogy. (1)

The analogy between pharmacology and pedagogy suggested that the former might offer a perspective to enrich the latter. The literature had nothing to offer in this respect. (2)

To pursue this suggestion, R. Fischer and F. Griffin discussed their research in pharmacology with E. Maccia and G. Maccia. From these discussions, pharmacology and pharmacogenetics emerged as an educational theory model.

II. THE EDUCATIONAL THEORY MODEL

Pharmacology and Pharmacogenetics

The study of the effect of drugs has been beset with difficulties which are common to all studies in which individual variation must be taken into account. Not all individuals respond equally to a given dose of a drug. How, then, can the dose of a drug in relation to a desired effect or response be defined?

Pharmacologists dealt with this question in terms of the recognition of one kind of individual variation given expression in Gauss' distribution curve. That is to say, there is continuous variation or the population forms one group in which there is more or less responsiveness. A familiar non-pharmacological example is the continuous distribution of the effect that concerned Alice. You can be anything from very short to very tall but with a likelihood of being somewhere around 5 ft. 8 in., assuming nutritional adequacy throughout. Consequently, 'the potency of a drug' was defined by the dose which produces a given effect in 50 per cent of the population.

The perspective entailed in a study centered about continuous variation neglected the other important kind of variation, discontinuous variation. The population might form more than one group. That this other kind of variation cannot be neglected in pharmacology is readily seen in Figure 1. One needs only to compare A and B. In A the population forms one group, and in B the population forms two groups.

Geneticists, on the other hand, whose business it is to study variation employed a perspective which did not limit variation to continuous variation. They distinguished between monofactorial inheritance and multifactorial inheritance. In monofactorial inheritance, single genes are the determiners. Depending upon whether you do or do not possess the single genes, you will or will not manifest the character. Usually such inheritance produces discontinuous variation or polymorphism. Blood groups are an example. You are either group A or group O or group B or group AB, and there is no grading. In multifactorial inheritance, many genes are the determiners. Depending upon whether you possess a few or a medium number or the complete set of genes, you will manifest less or more of the character. Height is an example.

In the light of discontinuous variation which pharmacologists did encounter, it was to be expected that their perspective should be broadened to

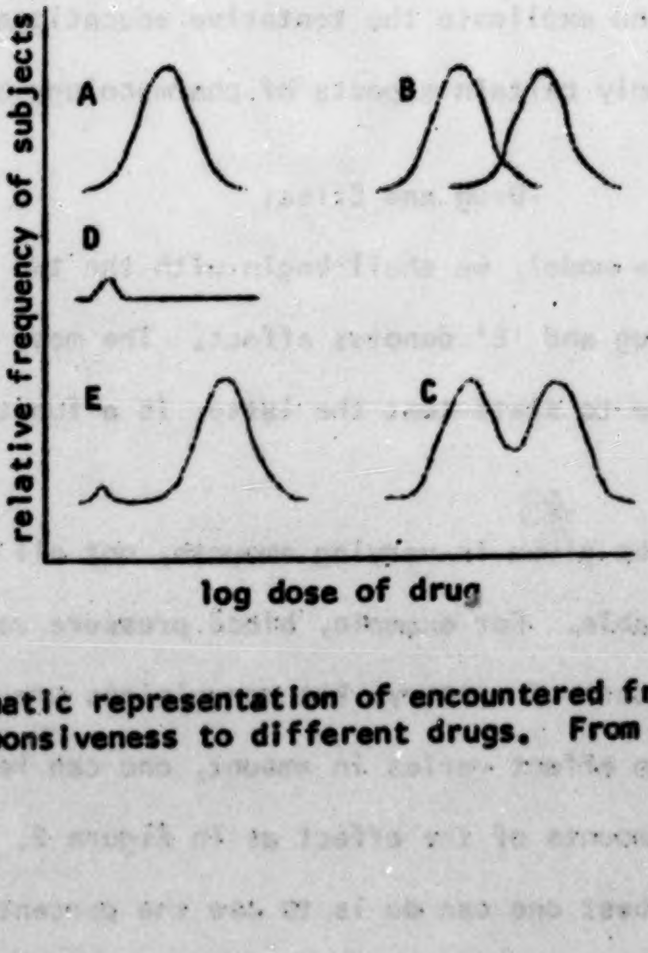

Figure 1. A schematic representation of encountered frequency distributions of responsiveness to different drugs. From Kalow, p. 213. (3)

include genetical considerations. They are heeding C. A. Clarke's call that

> more attention should be paid to the possibility that patients may deal with a drug in two or more distinctly different ways rather than manifest minor individual variations. (4)

Pharmacogenetics has emerged from pharmacology and genetics. (3)

The educational theory model now to be presented will involve this broadened perspective. Since not all of pharmacological and pharmacogenetic theory will be used to devise and explicate the tentative educational theory to follow, the model will include only certain aspects of pharmacology and pharmacogenetics.

Drug and Effect

In presenting the model, we shall begin with the two variables, 'D' and 'E' where 'D' denotes drug and 'E' denotes effect. The most general way of relating D and E would be to state that the latter is a function of the former, i.e. $E = f(D)$.

While drugs can be given in varying amounts, not all effects vary in amounts which are measurable. For example, blood pressure varies in amount which is measurable in millimeters of mercury, but convulsions are taken as either present or absent. If an effect varies in amount, one can relate varying amounts of the drug to varying amounts of the effect as in Figure 2. If an effect does not vary in amount, the best one can do is to use the percentage frequency of positive results (the effect is present) for each amount of the drug as a criterion of "effect" as in Figure 3.

However, pharmacologists are interested also in a more complex case. Their attention focuses on drug interaction in relation to effect. The relationship of concern is effect as a function of two or more drugs, i.e. $E = f(D_1, D_2, \ldots, D_n)$.

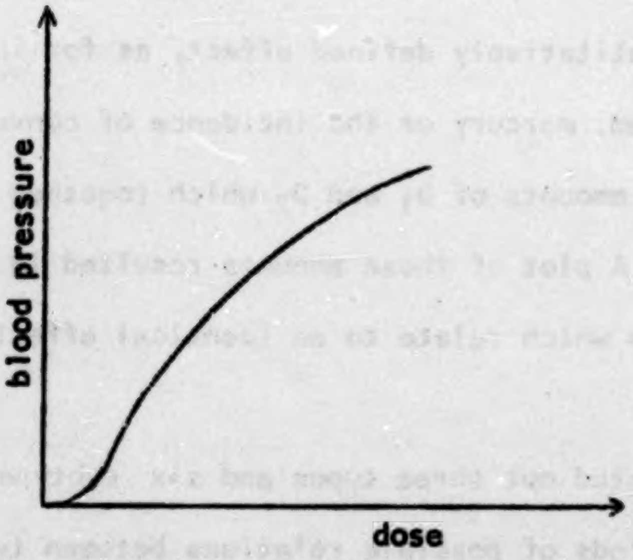

Figure 2. Dose-response curve. From De Jongh, p. 318. (5)

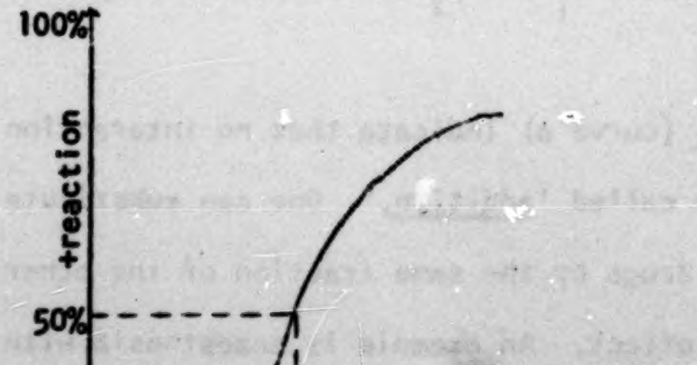

Figure 3. The relation between (log) dose and the frequency of a positive effect. From De Jongh, p. 319. (5)

In a review by S. Loewe in 1928 the isobole concept was introduced, so that the possible relations between two drugs in producing an effect could be analyzed and clarified. (6) The number of variables in $E = f(D_1,D_2)$ were reduced to two by choosing a quantitatively defined effect, as for instance an increase in blood pressure of 20 mm. mercury or the incidence of convulsions in 50 per cent of animals. The varying amounts of D_1 and D_2 which together produce the specified effect were determined. A plot of these amounts resulted in a curve whose points indicate the combinations which relate to an identical effect. Such a curve is known as 'an isobole.'

De Jongh has pointed out three types and six subtypes of isoboles in order to set forth the kinds of possible relations between two drugs in producing an effect. (5)

Type I isoboles (Figure 4) include those which have intercepts on both axes. Intercepts indicate that both D_1 and D_2 can produce the specified effect, if given alone.

Subtype Ia isoboles (curve a) indicate that no interaction occurs between D_1 and D_2. This is called 'addition.' One can substitute freely any fraction of one of the drugs by the same fraction of the other one, without changing the total effect. An example is anaesthesia with mixtures of chloroform and ether.

Subtype Ib isoboles (curve b) indicate interaction in which the drugs increase each other's effect. This is called 'potentiation.' When combining D_1 and D_2 to produce the specified effect, the requirement is less of each than in the case of addition. An example is the combination of morphium and ether with reference to their narcotizing effect.

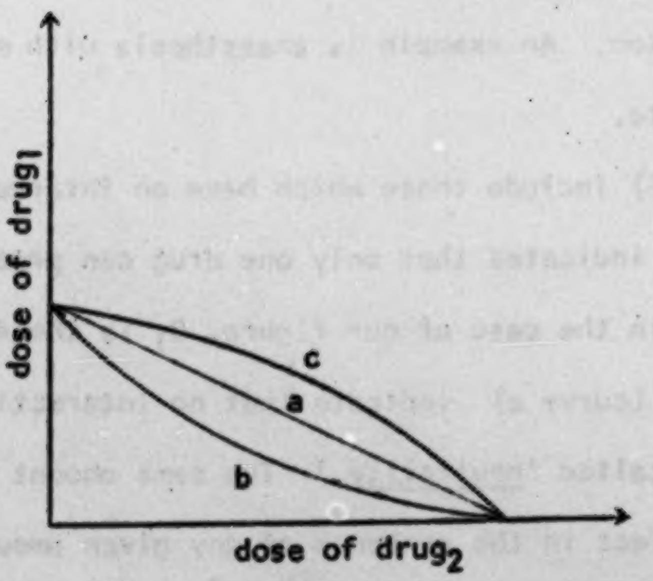
dose of drug$_1$
c
a
b
dose of drug$_2$

Figure 4. Type I Isoboles. From De Jongh, p. 320. (5)

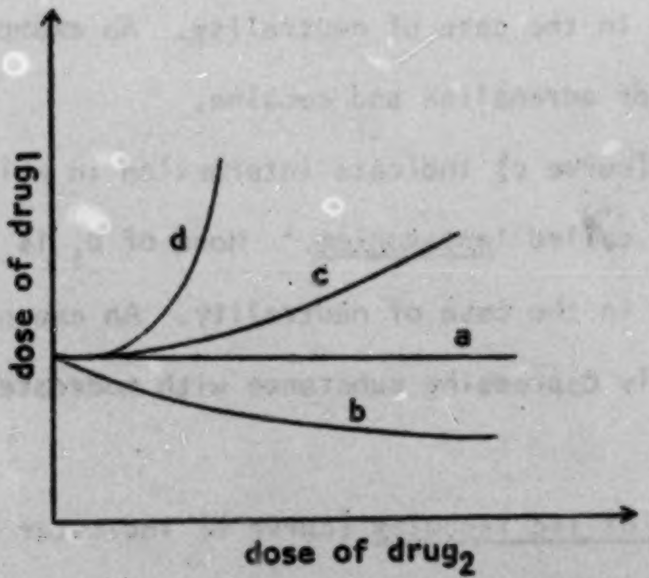
dose of drug$_1$
d
c
a
b
dose of drug$_2$

Figure 5. Type II Isoboles. From De Jongh, p. 321. (5)

Subtype Ic isoboles (curve c) indicate interaction in which the drugs reduce each other's effect. This is called 'depotentiation.' When combining D_1 and D_2 to produce the specified effect, the requirement is more of each than in the case of addition. An example is anaesthesia with mixtures of ether and magnesium sulphate.

Type II isoboles (Figure 5) include those which have an intercept on only one axis. Only one intercept indicates that only one drug can produce the specified effect, if given alone. In the case of our figure, D_1 is the drug that can do so.

Subtype IIa isoboles (curve a) indicate that no interaction occurs between D_1 and D_2. This is called 'neutrality.' The same amount of D_1 is required for the specified effect in the presence of any given amount of D_2 as in the absence of D_2.

Subtype IIb isoboles (curve b) indicate interaction in which D_2 increases D_1's effect. This is called 'augmentation.' Less of D_1 is required for the specified effect than in the case of neutrality. An example is the mydriatic effect with mixtures of adrenaline and cocaine.

Subtype IIc isoboles (curve c) indicate interaction in which D_2 decreases D_1's effect. This is called 'antagonism.' More of D_1 is required for the specified effect than in the case of neutrality. An example is the combination of any centrally depressing substance with moderate dosages of an analeptic.

The special case of IIc isoboles (curve d) indicates an antagonism in which a high enough amount of D_2 tends to prevent completely the specified effect. This is called 'blockage.' An infinitely large amount of D_1 is required for the specified effect. An example is the blockage of the effects of acetylcholine by a large dosage of atropine.

Type III isoboles (Figure 6) include those which have no intercepts. No intercepts indicate that neither drug can produce the specified effect, if given alone. Both drugs together, however, can produce the specified effect. D_1 and D_2 interact. This is called 'coalitive synergism.'

Taste as Pharmacological Effect

Taste--bitterness--is taken as a sensory expression of drug activity or the effect of a drug. (7) An example would be quinine, a drug, which results in a bitter taste sensation. Taste as an effect cannot be measured quantitatively. It is an all or none effect. What can be said is that there is a taste threshold for a drug which is the amount of the drug below which no taste occurs. Since taste has been taken as a sensory expression of drug activity, the taste threshold, therefore, becomes the dosage required for a drug to have an effect.

If two drugs are involved, then the taste threshold can be represented as an isobole. Figure 7 is one such isobole. 1.0 on the ordinate and abscissa indicate the taste thresholds for l-quinine sulfate and for 6-n-propylthiouracil respectively. Because both of the drugs taken by themselves have a taste threshold, this is an example of type I isoboles. Because the two drugs interact and increase each other's effect--potentiation occurs, this is an example of subtype Ib isoboles. (See page 192 of this report.)

Taste Thresholds as Pharmacogenetic Indicators

Differences in the taste thresholds of individuals to a given drug indicate variation. Stated differently, they may be regarded as "indicators of pharmacogenetic . . . peculiarities" (8). Depending upon the drug, this variation may be continuous or discontinuous. Figure 8 indicates continuous variation in the taste

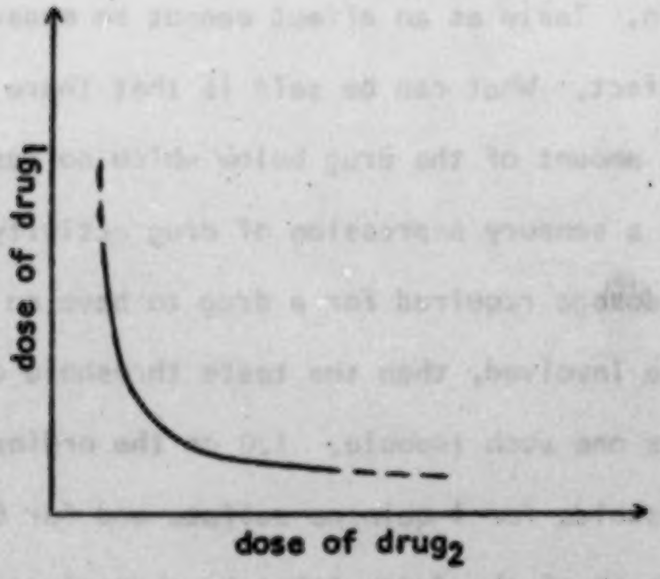

Figure 6. Type III Isoboles. From De Jongh, p. 322. (5)

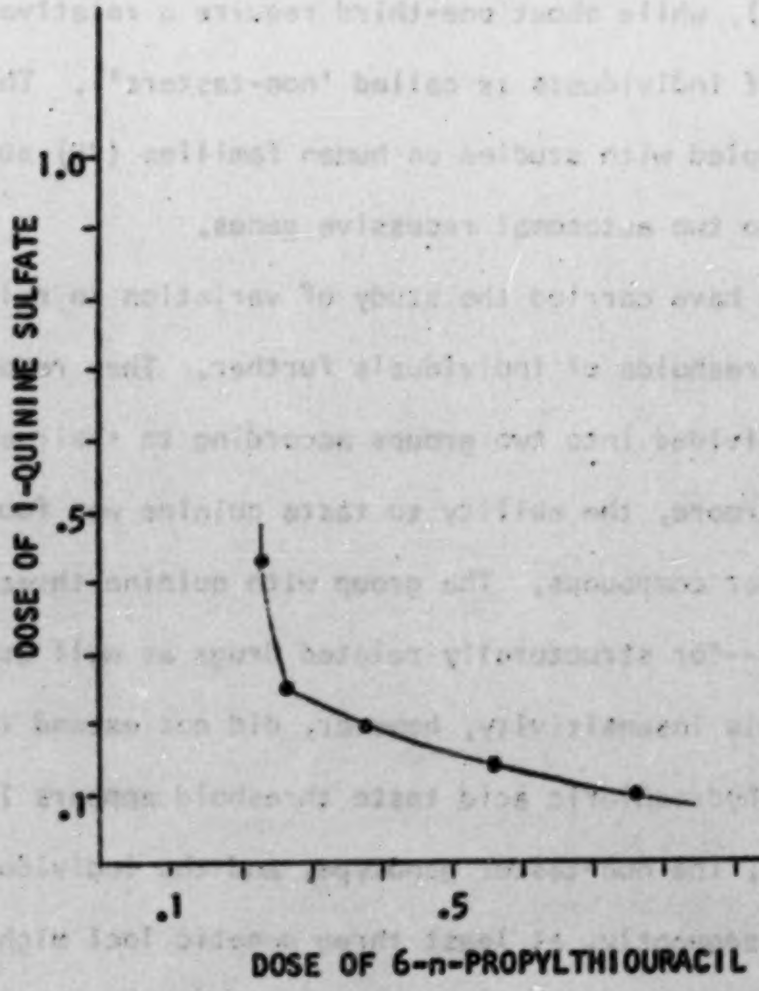

Figure 7. From Fischer *et al.* (7)

thresholds of individuals to quinine and discontinuous variation to phenylthiourea (PTC). In relation to PTC, about two-thirds are able to taste it in solution no. 7 (0.15 millimolar) or in lesser concentrations (this group of individuals is called 'tasters'), while about one-third require a relatively high concentration (this group of individuals is called 'non-tasters'). This discontinuous variation coupled with studies on human families (10) suggests that non-tasting of PTC is due to two autosomal recessive genes.

Fischer and Griffin have carried the study of variation in relation to differences in the taste thresholds of individuals further. They reported that non-tasters of PTC can be divided into two groups according to their ability to taste quinine. (11) Furthermore, the ability to taste quinine was found to relate to the ability to taste other compounds. The group with quinine thresholds 7 and above are high--insensitive--for structurally related drugs as well as sodium chloride and D-sucrose. This insensitivity, however, did not extend in all cases to hydrochloric acid. The hydrochloric acid taste threshold appears independent of the PTC taster phenotype, the non-taster genotype, and the individual's taste threshold for quinine. Consequently, at least three genetic loci might exist for taste: one for PTC-type substances, one for quinine and structurally related drugs as well as sodium chloride and D-sucrose, and one for hydrochloric acid and perhaps some other acids. (12)

Change in Taste Thresholds

Fischer and Griffin report that taste practice can change the taste threshold. (See Figure 9 based upon their investigation.) However, such change only takes place with compounds of certain specified structure. Also the time as

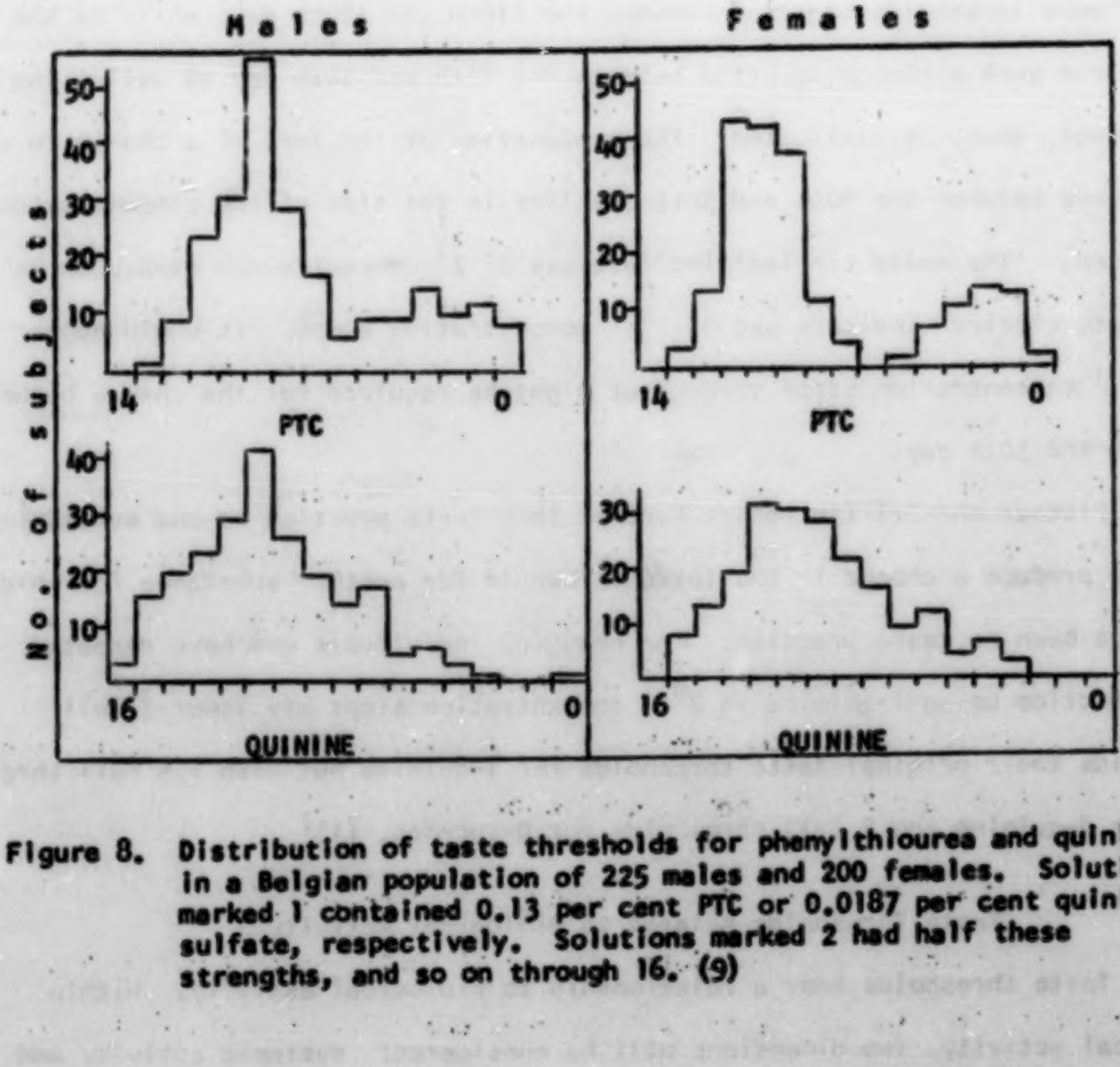

Figure 8. Distribution of taste thresholds for phenylthioureas and quinine in a Belgian population of 225 males and 200 females. Solutions marked 1 contained 0.13 per cent PTC or 0.0187 per cent quinine sulfate, respectively. Solutions marked 2 had half these strengths, and so on through 16. (9)

well as the size of the concentration steps are factors that must be considered. Both 6-n-propylthiouracil and l-quinine sulfate have the kind of structure that permits change in taste threshold through taste practice. These changes can be seen in both the upper and lower curves of Figure 9. In the upper curve a change of 3 or more thresholds occurred between the 110th and 120th day, while in the lower curve such a change occurred between the 40th and 50th day as well. The time factor, thus, is implicated. The explanation of the lack of a change in the upper curve between the 40th and 50th day lies in the size of the concentration steps used. 'The solid circles' indicate use of 2^1 concentration steps, while 'the empty circles' indicate use of $2^{0.1}$ concentration steps. It would appear that $2^{0.1}$ concentration steps throughout might be required for the change between the 40th and 50th day.

Fischer and Griffin report further that taste practice on one substance also may produce a change in the taste threshold for another substance for which there has been no taste practice. For example, individuals who have repeated taste practice using l-quinine in $2^{0.1}$ concentration steps may lower 3 full thresholds their original taste thresholds for l-quinine but also 1.5 full thresholds for d-quinine and 2 full thresholds for D-sucrose. (13)

Taste Thresholds Related to Biological Activity

Taste thresholds bear a relationship to biological activity. Within biological activity, two dimensions will be considered: systemic activity and receptor activity.

Fischer and his associates have posited that lower taste thresholds may be indicators of higher systemic activity for a drug. The basis for so doing is

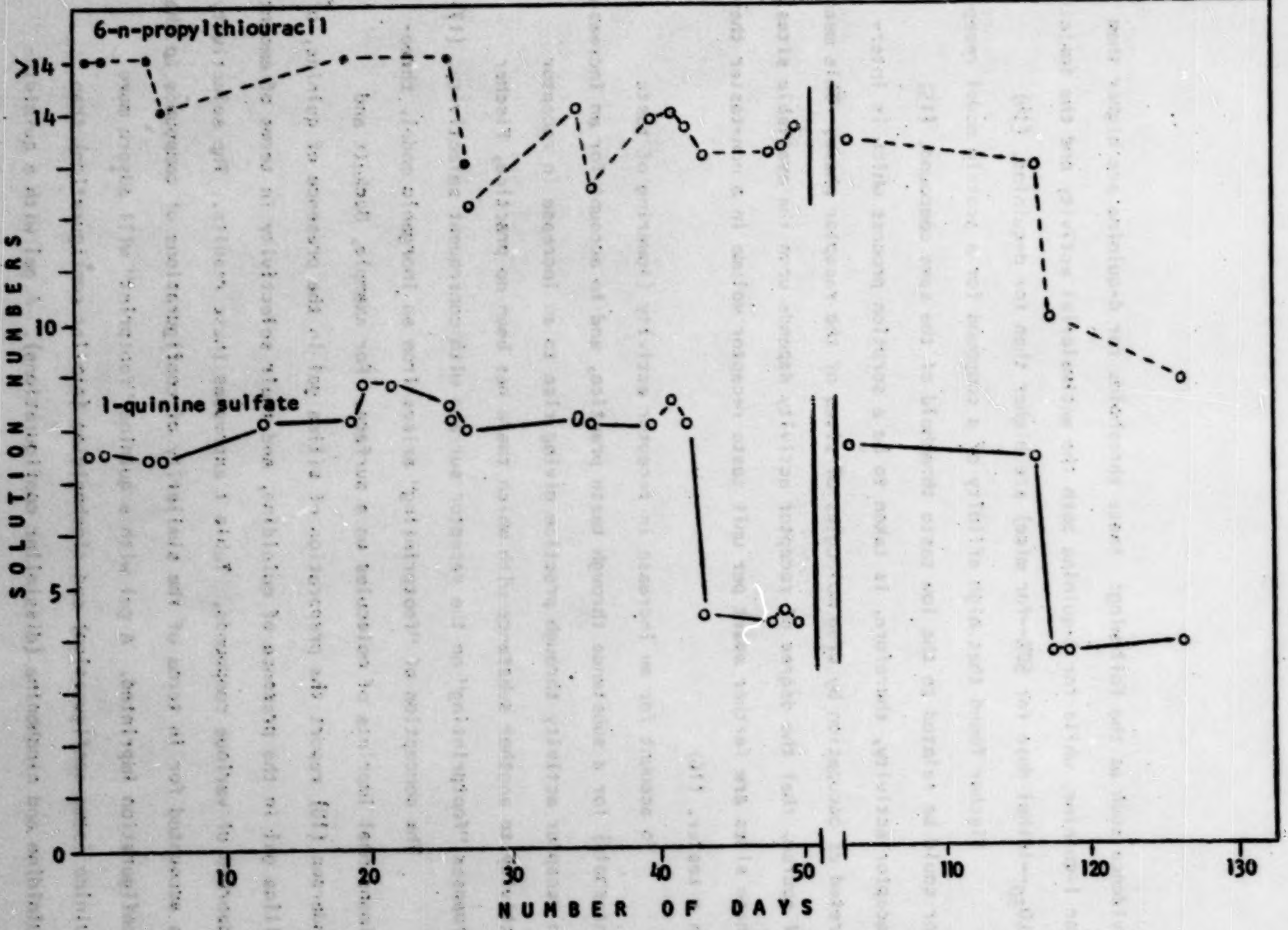

Figure 9. Change in taste threshold with practice. (13)

evidence such as the following: taste thresholds for d-quinine are higher than for l-quinine, while for l-quinine both the antimalarial activity and the toxicity (LD_{50}--lethal dose for 50%--for mice) are higher than for d-quinine. (14)

Fischer found that high affinity of a compound for a protein model receptor could be related to the low taste threshold of the same compound. (15) Receptor activity, therefore, is taken to be a sorption process which is interpreted as occupation by drug molecules of sites of the receptor phase. This means, of course, that the degree of receptor activity depends upon the available sites. These sites are farther apart per unit taste receptor volume in a non-taster than in a taster. (16)

To account for an increase in receptor activity (lowering of taste threshold) for a substance through taste practice, and to account for an increase in receptor activity through practice giving rise to an increase in receptor activity to another substance with which there has been no practice, Fischer proposes "footprinting" on the receptor surface with consequent selectivity. (17)

The conception of "footprinting" arises from an inorganic model, three-dimensional imprints of molecules on a surface. For example, Beckett and Anderson (18) report the preparation of silica gel in the presence of quinine, of silica gel in the presence of quinidine, and their selectivity in terms of amount adsorbed of various compounds. Table I expresses these results. The selectivity is accounted for in terms of the similarity of configurations of compounds to the configuration imprinted. A gel with a quinine "footprint" will adsorb more quinine (same configuration) and cinchonidine (similar configuration) than quinidine and cinchonine (dissimilar configurations). A gel with a quinidine

Table I. ADSORPTION OF STEREOISOMERS ON A QUININE-SELECTIVE ADSORBENT AND A QUINIDINE-SELECTIVE ADSORBENT

1 gm. of adsorbent used to 10 gm. of solution ($25 \cdot 0 \times 10^{-5}$ mole per kgm. in 5 per cent acetic acid)

Adsorbent	Batch No.	Uptake expressed as moles $\times 10^5$/kgm. of adsorbent of			
		Quinine	Quinidine	Cinchonine	Cinchonidine
Quinine-selective adsorbent	1	217	160	163	207
	2	210	161	167	200
Quinidine-selective adsorbent	1	194	224	218	190
	1	196	228	215	193

"footprint" will adsorb more quinidine (same configuration) and cinchonine (similar configuration) than quinine and cinchonidine (dissimilar configurations). Also it is important to note that a blank gel will not adsorb as much quinine as one with a quinine imprint. (19)

Utilizing this model, the lowering of the taste threshold for l-quinine through practice could be accounted for in terms of increased selectivity to l-quinine due to its imprinting on the receptor surface. Also the partial lowering of the taste threshold for d-quinine without practice when l-quinine practice has been lowering taste thresholds could be accounted for in terms of increased selectivity due to configurational similarity. The explanation for the lowering of the taste threshold for D-sucrose without practice when the l-quinine threshold has been lowered through practice is not as straightforward. However, Fischer has suggested increased selectivity due to the possibility of configurational fitting of D-sucrose to the imprinted l-quinine on the receptor surface. Compounds with one asymmetric carbon atom, such as D-sucrose, are able to fit at least one site of a $C_8 - C_9$ site of the l-quinine imprint. (17)

Referring once more to the lower curve in Figure 9, it is noticed that the increased selectivity of the receptor surface to l-quinine, which is supposed to be brought about through imprinting of l-quinine, is lost if practice is not continued. Compare the lowered taste threshold of day 50 with the threshold of day 100, and note that days 51 through 100 are without taste practice. Returning once more to our inorganic model, silica gel with "footprints," a similar phenomenon is noted. Storage of silica gel with quinine footprints at 37° gives some loss of selectivity, while storage in a refrigerator for 6 months gives no change in selectivity. (19) Utilizing this model once again, some factor must be related to the loss of selectivity of the receptor surface. Since taste receptor cells undergo regeneration (20), such regeneration could account for the loss. With the generation of a new receptor surface for the old, the imprint must of necessity disappear. More, however, must be involved, for the lower curve in Figure 9 also shows a more rapid regaining of increased selectivity after loss of imprinting on the receptor surface. The imprinting on the new receptor surface somehow is facilitated. Perhaps there is also a cortical imprinting as well as a receptor imprinting. This appears likely, as taste not only depends upon substance-receptor interaction, but also upon registration as sensory perception in cortical centers. The cortical imprinting that remains when the receptor imprinting is lost could account for this rapid regaining of selectivity.

III. THE EDUCATIONAL THEORY

Pedagogy and Pedagotypology

Pedagogy, just as pharmacology, has been beset with the difficulty of taking into account individual variation. The effect of a teaching is not the same for all students. In fact, that the teacher should concern himself with individual differences has become a "commandment" of the teaching profession.

Pedagogists (21), just as pharmacologists, dealt with this difficulty in terms of the recognition of one kind of individual variation given expression in Gauss' distribution curve. Variation is taken to be continuous. That is to say, the population of students forms one group in which, if subjected to a teaching, the effect is present throughout to a greater or lesser extent with the likelihood that most students would exhibit it to a similar degree. For example, if the PSSC (Physical Science Study Committee) materials are used in a class, it is expected that achievement will be present throughout to a greater or lesser extent with the likelihood that most students would exhibit it to a similar degree. The class is viewed as a sample of the population of students that forms one group. Therefore, in comparing the effectiveness of two teachings, the perspective of continuous variation obtains. For example, if the PSSC materials are compared with other physical science materials, it is done in terms of difference in achievement in two classes, where again achievement to the respective materials is thought to be present throughout the respective class to a greater or lesser extent with the likelihood that most students would exhibit it to a similar degree. Each class is viewed as a sample of the population of students that forms one group in regard to achievement. To underline the prevalence of this perspective of continuous variation, one merely has to point to the field of educational achievement testing.

The educational theory to be presented will be framed, so that pedagogists might deal with the difficulty of individual differences within a broader perspective of variation, i.e. discontinuous as well as continuous variation. The suggestion is that the population of students will form more than one group in respect to an effect due to a teaching. For example, the population of students might form with respect to PSSC materials two distinct groups: one we shall call 'achievers' and the other, 'non-achievers.' The supposition would be that achievement would be confined within high values for the achievers and low values for the non-achievers. (Notice that 'non-' is taken in a relative sense; but could be considered essentially as none, since the relative values are low.) Of course, within each group there would be variation within its value limits. The result of such a broadened view would be the emergence of a typology of teaching in relation to student population. The difference between teachings would no longer simply be within the perspective of difference in degree of an effect. The added perspective would be all or none. The comparison of teachings as to difference in degree of an effect would be restricted to teachings within the same type. To summarize, pedagogy will be broadened to include typology. So pedagotypology (2) will emerge from pedagogy.

Teaching and Effect

In presenting the educational theory, we shall begin with two variables, 'T' and 'E' where 'T' denotes teaching and 'E' denotes effect. The most general way of relating T and E would be to state that the latter is a function of the former, i.e. $E = f(T)$.

Teaching, however, involves more than one variable. In any one teaching, there is something taught--content--and the way in which it is taught--method. To illustrate, in teaching chemistry two different contents could be atomic theory and the properties of oxygen. In teaching the properties of oxygen, two different methods could be lecturing--the teacher telling about a property of oxygen such as 'how little oxygen is soluble in water at room temperature'--or demonstrating--the teacher manipulating apparatus such as an oxygen generator, glass bottles, and a water trough to show how little oxygen is soluble in water at room temperature.

To be sure, more would be required to specify content and method in the above illustrations. Consider that the content of atomic theory presented as language--a writing or a saying--would need specification in terms of language. Two different writings or sayings of atomic theory might not involve the same content. Since many methods of presenting content involve teacher-saying and teacher-writing, the language behavior of the teacher would enter often into the specification of content. Consider too that the method of lecturing involves not only specification in terms of teacher behavior, but also in terms of student behavior. There is not only teacher-saying, but also student-listening and student-writing. 'Teacher-telling' means just this. Finally, consider the further specification required in the light of technological advances. Lecturing could be via television.

The above discussion of specification has pointed up that teacher and student behaviors are caught up in the content and method variables. (23) Consequently, the relationship between teaching and effect can be stated by means of three variables, i.e. $E = f(C,M)$ where 'C' denotes content and 'M' denotes method.

To further extend this portion of the educational theory, what would be required is a working out of a taxonomy of content and of method. Such a taxonomy would provide dimensions in terms of which the content and method variables could be specified.

Since no effect will occur with content alone or with method alone, one cannot state correctly that $E = f(C)$ and $E = f(M)$. Only content and method together will produce an effect. That is to say, one can state correctly only that $E = f(C,M)$. The model suggests that coalitive synergism occurs between content and method to produce an effect. 'Coalitive synergism' means, of course, that interaction takes place between C and M.

The usual way of handling the complex treatment required by three variables, is to fix the value of one variable. In pedagogy, the approach has been to hold either the content or method constant. One could state correctly, therefore, that given a certain value of C then $E = f(M)$ or that given a certain value of M then $E = f(C)$. Since the interest of the pedagogist is in a comparison of contents or methods in relation to effect and because coalitive synergism between content and method occurs, this approach presents an inherent difficulty. It might well be the case that only at the given value of content, is the one method more effective than the other. At another value of content, the situation might be reversed. The same, of course, might be true if the value of method were specified and contents compared. (24)

The model indicates another way of approach that would not present the above difficulty. The approach is one in which *the effect is held constant*. If the effect were held constant, then we could determine the ratios of content to method that were required for the specified effect. How could this way of approach give us a comparison of contents or methods? To answer this question, let us utilize a set of hypothetical curves, A and B, as set forth in Figure 10. We shall consider the case of comparing methods. From our curves we can construct Table II which indicates the amount of the method involved in A as compared with the amount of the method involved in B for a given amount of content needed to give the specified effect. From this table, it can be noted that the method in A is more effective, in the sense that less is required for the effect, than the method in B until the content reaches a value of 9. At 9, the two methods are equal in effectiveness. Beyond 9 the method in B becomes more effective.

Our assumption, thus far, has been that one method together with one content is related to effect. The case becomes more complex when more than one method or more than one content is involved. Consider the following relationship, $E = f[(C),(M_1,M_2)]$. The question, then, arises whether interaction takes place

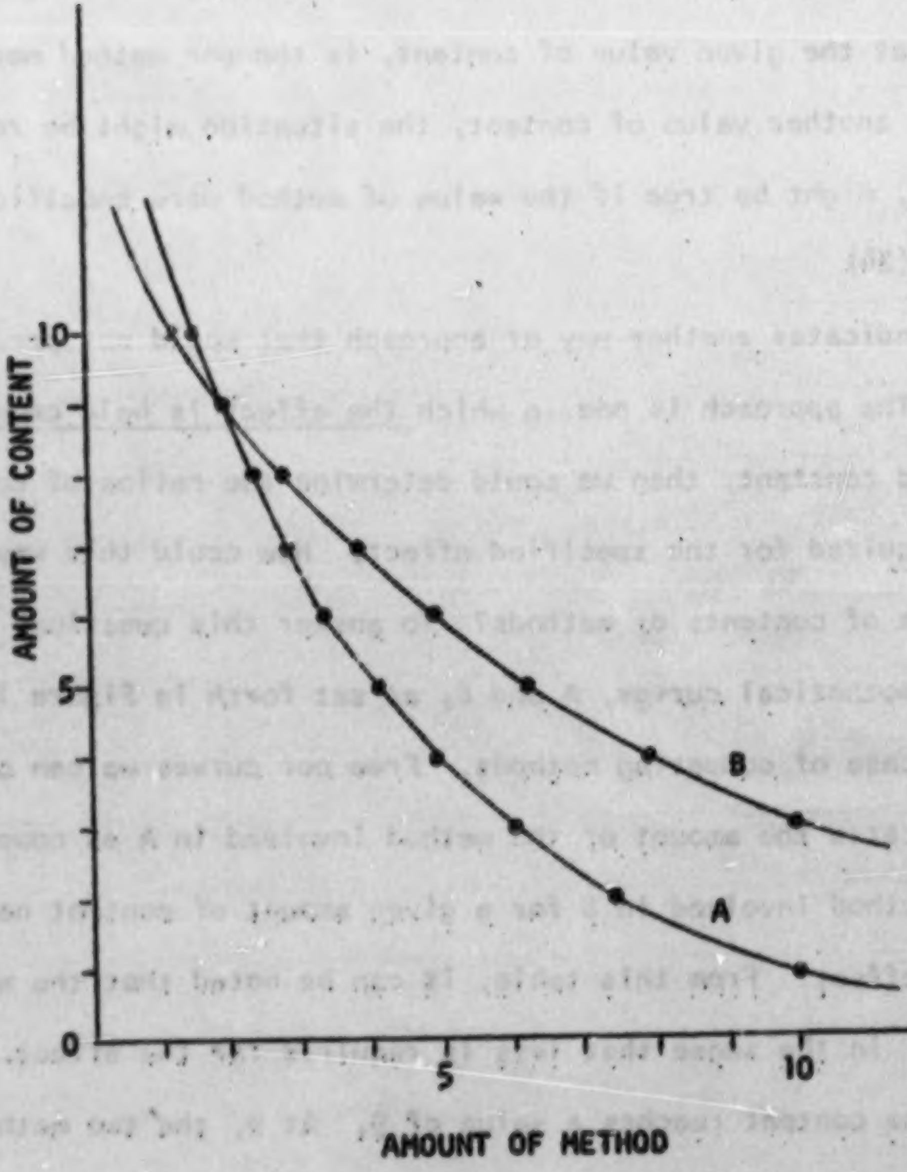

Figure 10.

Table II: COMPARISON OF METHODS

Amount of the Content	Amount of the Method Involved in	
	A	B
1	10.0	>10.0
2	7.5	>10.0
3	6.0	10.0
4	5.0	8.0
5	4.5 - 4.0	6.5 - 6.0
6	3.5	5.0
7	3.0	4.0
8	2.5	3.0
9	2.0	2.0
10	2.0 - 1.5	1.5 - 1.0

between the two methods. If it does, is it coalitive synergism, as between content and method, or some other kind? The same question, of course, could arise in regard to interaction of more than two methods and interaction of contents. The model suggests the following possible interactions that would have to be considered in answering this question. (See pages 192 through 196 of this report.)

Type I interactions (Type I isoboles) include those between methods each of which by itself in conjunction with a specified content can produce a specified effect. All of the methods in and of themselves in conjunction with a specified content are effective with respect to a specified effect.

Subtype Ia interactions (Subtype Ib isoboles) are potentiations in which the methods when they are together increase one another's effectiveness.

Subtype Ib interactions (Subtype Ic isoboles) are depotentiations in which the methods when they are together decrease one another's effectiveness.

Type II interactions (Type II isoboles) include those between methods not all of which by themselves in conjunction with a specified content can produce a specified effect. Only some of the methods in and of themselves in conjunction with a specified content are effective with respect to a specified effect.

Subtype IIa interactions (Subtype IIb isoboles) are augmentations in which the non-effective together with the effective methods increase the latter's effectiveness.

Subtype IIb interactions (Subtype IIc isoboles) are antagonisms in which the non-effective together with the effective methods decrease the latter's effectiveness.

Type III interactions (Type III isoboles) are coalitive synergisms in which together the methods do what they cannot do when taken by themselves, i.e. in conjunction with a specified content produce a specified effect. The possible interactions would hold also when contents rather than methods are involved.

Given the above possibilities as to kinds of interactions, the answering of the question as to whether interaction obtains between methods or between contents, and if so what kind, is complex. Not only must effect be specified, but also either content or method. Depending upon the latter specification the question well might be answered differently, since coalitive synergism between content and method holds.

To illustrate the answering of the question when two methods are involved, the hypothetical curves in Figure 10 and the hypothetical data in Table II will be utilized. Furthermore, we shall assume that the possible interaction of the method in A and the method in B to produce the specified effect which was the basis for the curves is what concerns us. Next we shall specify the content at 9. This specification indicates that interaction, if present, would have to be of Type I, for both the method in A and the method in B in conjunction with a value of content which is 9 can by themselves produce the specified effect. Each method at a value of 2 produces the specified effect. If it is discovered that in combination the amount of method in A and the amount of method in B must add up to 2 to give the specified effect, then no interaction between methods takes place. Addition occurs. Potentiation, however, would occur, if the combinational amount need be less than 2. Now interaction takes place. The final possibility would be the interaction in which depotentiation occurs, i.e. the combinational amount must be more than 2.

Student Behavior as Pedagogical Effect

The model indicates that student behavior be taken as an expression of teaching activity or the effect of teaching. An example would be the wanted language behavior of the student as an expression of lecturing about the atomic theory. To measure that language behavior, a usual procedure would be to have the students respond in writing to questions. This test, then, becomes a test of the teaching through measuring a wanted effect.

Measurement of wanted student behavior entails the working out of a taxonomy of objectives. (25) If such a taxonomy were done well, it would provide the required dimensions by means of which wanted effects could be specified. That is to say, the taxonomy must not be restrictive so that wanted effects are ruled out, and it must not be expressed so that quantification is impossible. Both comprehensiveness and measurability are required.

Given a specified student behavior, the model suggests a student behavior threshold which is the amount of a teaching below which that specified student behavior does not occur. Since both content and method are involved in a teaching, the expression of a student behavior threshold would be by means of an isobole. Figure 10 presents two such hypothetical isoboles. Because neither content nor method taken by themselves have a student behavior threshold, coalitive synergism obtains.

Student Behavior Thresholds as Pedagotypologic Indicators

Just as differences in the taste thresholds of individuals to a given drug indicate variation, so differences in the student behavior threshold to a given teaching indicate variation. One may state, therefore, that student behavior thresholds are indicators of pedagotypologic peculiarities.

If the only variation considered were continuous, then the pedagotypologic peculiarities with respect to teachings that do produce a given effect would be a matter of degree. All students would behave in a certain way to one of these teachings, but the degree of that behavior would not be the same. These teachings, of course, could differ in effectiveness. It might take more of one than of another to produce the same degree of the given effect. Essentially, then, all teachings producing a given effect form one type with respect to student population. The task would be to pick the most effective teaching. Since there is only one type, type would not be a matter of concern.

If on the other hand, discontinuous variation were considered also, then the pedagotypologic peculiarities with respect to teachings that do produce a given effect could be a matter of kind. All students might not behave a given way to one of these teachings. Rather the students might form two groups--one of which does behave in a given way and one of which does not behave in a given way. Essentially, then, all teachings producing a given effect would form more than one type with respect to student population. The task still would be to pick the most effective teaching, but this would depend upon first developing a typology of teaching in relation to student population.

Change in Student Behavior Thresholds

The model relates practice to a lowering of taste thresholds. Not all practice will do so. The factors--what is practiced, how it is practiced, and the length of time of practice--condition the outcome of practice. Paralleling the model, it is postulated that practice with certain teachings can lower the student behavior thresholds to those teachings, provided that the amounts of each of the teachings are lowered in small enough steps over a long enough period of time.

The model further indicates that practice with a drug when it is lowering the taste threshold for that drug will in certain cases also lower the taste threshold for another drug with which there has been no practice. In a similar vein, this theory proposes the possibility that practice on one given teaching when it is lowering the student behavior threshold for that teaching will lower the student behavior threshold for another teaching with which there has been no practice.

Student Behavior Thresholds Related to Psychological Activity

Student behavior thresholds should bear a relationship to psychological activity, just as taste thresholds bear a relationship to biological activity. Psychological activity will be considered as involving two dimensions: drive activity and cognitive activity.

The attempt to get behind surface activity to the roots of human action has given rise to the motive construct. Behavior is related to motives which are expressions of drive activity. To illustrate, both exuberance and irritability, which are behaviors that are habituated and so are considered traits, are related to agression, an expression of drive activity. In fact, Else Frenkel-Brunswik found the relation to be one of positive correlation. (26) Student behavior, then, should be related to drive activity. In fact, the model points to lower student behavior thresholds as indicators of higher drive activity. What expressions of drive activity are important in this connection is another problem.

This problem is complex, since the classification of possible motives is still open. However, McCelland, on the basis of the situation of the infant and the problems he has to face, has suggested: a cluster of motives dealing with safety, another dealing with affiliation, a third with achievement, and a fourth with frustration reduction or avoidance of anxiety. (27) It would appear that all four clusters of motives could be implicated in student behavior.

The attempt to get behind surface activity also has given rise to a consideration of cognitive activity. Behavior is also related to cognitive activity. 'Cognitive activity' is not taken in any narrow sense. Following the model, it is an experiencing which is interpreted as occupation by the stimulus (that which is experienced) of sites in a man's mind. This means, of course, that the degree of cognitive activity depends upon the available sites. In the context of teaching as a stimulus, cognitive activity would be the occupation by the teaching (that which is experienced) of sites in a man's mind. The degree of cognitive activity in this context too would be dependent upon the available sites. Low student behavior threshold, therefore, would be related to high cognitive activity which in turn is related to a large number of available sites. The above statements, of course, are not to be taken in any literal spatial sense.

The schema construct has been related to cognitive activity. Schemas are taken to be "residues of experience . . . that serve to make up the contents of a man's mind." (28) The concept of schema parallels the concept of footprint in the model. Just as footprinting is an imprinting of the molecular configuration of the drug upon the receptor surface, so schematizing could be the imprinting of the configuration of the stimulus upon the cognitive surface. To illustrate, two divergent examples will be cited. In response to teaching involving content related to producing a motor behavior such as driving a car, this content could be imprinted as a posturing (probably a configuration dealing with positioning in space-time). (29) In response to teaching involving content related to producing language behavior such as writing or saying '2 + 2 = 4,' this content could be imprinted as a conceiving (probably a configuration dealing with a taking together of symbols).

Through the concept of schema, just as through the concept of footprinting, selectivity in regard to cognitive activity is proposed. The contents of a man's mind, schemas, relate to other possible cognitive activity. More experiencing of the stimulus (teaching) will take place (the student behavior threshold will be lower), if the configuration of the teaching is similar to the configurations already imprinted--the schemas. Consider the similarity in configurations between one kind of mathematics and another, the similarity in configuration between mathematics and the physical sciences, and the dissimilarity between sciences and the humanities. Consequently, practice with one content of mathematics should lower the student behavior threshold not only to this content, but also to other kinds of mathematics and to physical sciences. It should not, however, lower the student behavior threshold to the humanities.

The model points to the possibility of configurations that are not similar but that could fit with one another. (Practice with l-quinine lowered the taste threshold for D-sucrose.) Another reason, therefore, why practice with mathematics may lower the student behavior threshold to the physical sciences might be that some of the schemas produced by teaching the content of mathematics fit with the schemas produced by teaching the content of the physical sciences. Mathematics does provide the calculi for the physical sciences. Would we be accused of groundless supposition, if we suggested a general education might be devisable which produces schemas that permit the most fitting of yet other schemas? Thus, undue selectivity or narrowing of perspective might be avoided, if this is what is desired and desirable.

IV. SIGNIFICANCE OF PHARMACOLOGY AND PHARMACOGENETICS

The educational theory presented in the last section is quite tentative. Enough development, however, has been undertaken to establish pharmacology and pharmacogenetics as an educational theory model. That it is not a model for sheer rather than adequate speculation about educative phenomena depends upon the relevance and fruitfulness of the tentative educational theory. That is to say, are there studies which fit in with the theory and does the theory suggest yet other studies? Even though there is a certain patent relevance and fruitfulness that must have occurred to one as they read the tentative theory, nevertheless it will be spelled out and the less obvious relevance and fruitfulness will be indicated.

As stated earlier, pedagogy is a study of long-standing. Relationships between different kinds of effects and different kinds of teachings have been sought. Furthermore, different kinds of teachings have been compared as to their effectiveness. Unfortunately, the results of these studies have been disappointing.

> Until comparatively recently, much research in educational methodology was confined to the so-called "named methods." . . . The common research design involved comparison of the results obtained through the use of the named method in contrast with results obtained through use of a control method. . . . Reports of this research reveal the inconclusive nature of much of the evidence obtained and in many cases demonstrate that the evidence, taken as a whole is internally contradictory. (30)

The disappointment could be due to conceptual inadequacies which our tentative theory seeks to eliminate.

Consider that the theory calls for a development of taxonomies of effect (objectives), of content, and of method. Unless such taxonomies, stated so that the development of measures is possible, are forthcoming, how can variables be specified? Specification is essential to determining anything. Furthermore, the taxonomies must not be narrowed unduly, so that what is specifiable is exclusive of phenomena of concern. Bloom and others made a start at a taxonomy of objectives and also recognized that it would "provide the detailed specification for the construction and use of evaluative techniques." (31) Harris reported little attention to Bloom and his associates' attempt and decried this lack:

> . . . the materials in the chapter on achievement testing suggest that no one is trying to define achievement--except in the obvious manner of labeling content. Apparently the Taxonomy of Educational Objectives (Bloom and others, 1956) has had no influence during this period. Granted, this taxonomy is incomplete and what is available could be reworked with some gains; it still is unfortunate that there is no active work reported that seeks to employ this schema to limit and distinguish among definitions of achievement or to check out the relationships among the types of achievement suggested by it. We are in the doldrums! (32)

Bruner's concept of structure (33) has stimulated discussion of the structure of knowledge. If this discussion should reach fruition in a careful working out of structure, then surely this would be a partial basis for a taxonomy of content. The work of B. O. Smith and his associates (34) also should contribute to a taxonomy of content as well as one of method, since teacher language behavior usually is involved in a content as well as a method.

The theory also points up the need to consider content and method as interacting to produce effect. This recognition was voiced by Taylor who found no significant difference when he compared a lecture method with a small-group discussion method:

> Since the teaching methods used in this study were equally effective when learning experiences were held constant, a series of studies should be designed and executed to determine the effectiveness of various methods and experiences combined. (35)

The theory postulates that the interaction between content and method is a coalitive synergism and also suggests a way of approach that would take this into account when methods are compared, i.e. holding the effect constant.

Possible interactions between methods or between contents are acknowledged in the theory. The instructional gestalt is not neglected. As Siegel puts it:

> There is a pronounced tendency to neglect what has been termed the 'instructional gestalt' in favor of investigating the impact of a single class of variables which may contribute to the gestalt. The effect here may be that of obscuring certain critical interactions among variables. (36)

The theory does not stop here, but suggests possible kinds of interactions. This should be fruitful in giving meaning to the interaction variances which are measured in more sophisticated designs.

The postulation of student behavior thresholds relates to the studies on readiness. In fact, by replacing the term 'readiness' with 'student behavior threshold,' one might reduce the ambiguities of kinds of readiness and their interrelation: mental readiness, emotional readiness, and educational readiness.(37) There would be simply a student behavior threshold (readiness), and this would be related to psychological activity (motives which could be what is entailed in the so-called 'emotional readiness' and schemas which could be what is entailed in the so-called 'mental readiness').

The finding of Gallagher and Lucito that gifted, average, and retarded subjects had different subtest patterns on the Wechsler Intelligence Scale for Children and their speculation that different patterns of curriculum and methods of teaching should be used to reflect the varying patterns of intellectual abilities (38) fits in with the pedagotypologic dimension of the theory.

In this theory the student was dealt with in terms of his behavior, his motives, and his schemas. This threefold analysis agrees with what McCelland has argued to be adequate dimensions for describing personality. (27) Finally, the emphasis on schemas should be a fruitful extension of the theoretical orientation of Bruner (33) which emphasizes cognitive structure. Acquiring of wanted student behaviors (learning) requires the incorporation of new teachings into an established (imprinted) cognitive framework, schemas. This incorporation depends upon structural similarity or structural fitting of the new teachings and the old which have become the schemas of the students. This relates to studies of transfer and practice. Transfer, the impact of prior teachings on new teachings, should be positive (proactive facilitation) where there is structural similarity or fit, and negative (proactive inhibition) where such similarity and fit is lacking. Ausubel and Blake, for example, showed that meaningful learning of a passage of Buddhism was not adversely affected by recent prior learning of Christianity. (39) If transfer where not in a context of cognitive structure, proactive inhibition would be expected between these two stimuli. Ausubel's organizers (inclusive subsuming concepts) relate to the notion of schemas permitting the fit of other schemas. He found that undergraduates exposed to organizers were able to learn better unfamiliar content. (40) Practice on one kind of teaching transferred to the other kind of teaching.

Undoubtedly, there is yet other relevance and fruitfulness to be pointed out. This brief survey, however, should have established the tentative theory as one that is not sheer speculation. The pharmacological and pharmacogenetic model surely is significant for the doing of educational theory.

FOOTNOTES

(1) Pedagogy is, of course, a study of long-standing. The term has not been used for some time in the United States, perhaps due to the hostile implications--dogmatism, severity; and pedantry--associated with the term 'pedagogue.' For those who cannot disassociate themselves from the hostile implications, the term 'educatology' is offered as a substitute.

(2) The literature shows only an interest in relating pharmacology to behavior in terms of behavioral effects of drugs. 'Psychopharmacology' is the term utilized for such a relating. An example would be the report of E. S. Levine, "Can We Speed Up the Slow Child?: Preliminary Report of the Effect of Glutanic Acid Administration Upon the Mental Function of the Slow, Deaf Child," in Volta Review, Vol. 51, 1949, pp. 269-270.

(3) For a comprehensive treatment of pharmacogenetics, see the work by Weiner Kalow (Philadelphia: W. B. Saunders Company, 1962) which is so titled.

(4) "Pharmacogenetics--A Study of Inherited Variability in the Response to Drugs," in The Journal of Pharmacy and Pharmacology Supplement, Vol. 14, 1962, p. 29T.

(5) See S. E. De Jongh's treatment of isoboles (pp. 318-327) in Quantitative Methods in Pharmacology: Proceedings of a Symposium Held in Leyden on May 10-13, 1960, Amsterdam: North-Holland Publishing Company, 1961.

(6) This review appeared in Ergebnisse der Physiologie.

(7) For a comprehensive treatment of taste in a pharmacological and pharmacogenetic context, see the work of Roland Fischer and his associates which is summarized in "The Perception of Taste: Some Psychophysiological, Pathophysiological, Pharmacological and Clinical Aspects," in Psychopathology of Perception, ed. by Zubin and Hoch, New York: Grune and Stratton, in press.

(8) Fischer, op. cit. (7), p. 2 of mimeographed copy.

(9) A. Leguebe, "Génétique et anthropologia de la sensibilité a la phenylthiocarbamide: 1 Fréquence de gène dans la population belge," in Bull. Inst. Roy. Sciences naturalles Belgique, Vol. 36, No. 1, 1960, as cited in Kalow (3), p. 121.

(10) See A. F. Blakeslee, "Genetics of Sensory Thresholds: Taste for Phenylthiocarbamide," in Proc. Nat. Acad. Sci., Vol. 18, 1932, p. 120; and L. H. Synder, "Studies in Human Inheritance: IX. The Inheritance of Taste Deficiency in Man," Ohio J. Sci., Vol. 32, 1932, p. 436.

(11) 'Factors Involved in the Mechanism of "Taste-blindness",' in J. Hered, Vol. 2, 1960, p. 182.

(12) Pages 20-21 of the mimeographed copy of the summary cited in (7).

(13) Unpublished findings, 1963.

(14) Pages 16-18 of the mimeographed copy of the summary cited in (7).

(15) See R. Fischer, Publ. No. 1, Amer. Inst. Biol. Sci., edited by R. G. Grenell and L. J. Mullins, 1956; R. Fischer, "Selection on the Molecular Level: Biological Role of Drug-Protein Interaction," in Proc. Intern. Symp. Structure and Biol. Function of Proteins, Berlin: W. Humboldt University, in press; and R. Fischer, F. Griffin, and L. Liss, "Biological Aspects of Time in Relation to (Model) Psychoses," in Ann. N. Y. Acad. Sci., Vol. 96, 1962, pp. 44-65.

(16) T. R. Rubin, F. Griffin, and R. Fischer, "A Physico-Chemical Treatment of Taste Thresholds," in Nature, Vol. 195, 1962, pp. 362-364.

(17) R. Fischer, F. Griffin, and A. R. Kaplan, "Pharmacogenetic Aspects of Taste," in Proceedings of the XIth Intl. Congress of Genetics, The Hague, Sept. 1963, in press.

(18) 'A Method for the Determination of the Configuration of Organic Molecules Using "Stereo-selective Adsorbents",' in Nature, Vol. 179, 1957, pp. 1074-1075.

(19) A. H. Beckett and P. Anderson, '"Footprints" in Adsorbents,' in The Journal of Pharmacy and Pharmacology Supplement, Vol. 11, 1959, pp. 258-260.

(20) According to J. L. Henry et al. ("Pattern of Mitotic Activity in Oral Epithelium of Rabbits," in A.M.A. Archives of Pathology, Vol. 54, 1952, pp. 281-297) cells in the oral cavity of a rabbit may have an average life of only 208 hours. Furthermore, L. Beidler ("Taste Receptor Stimulation," in Progress in Biophysics and Biophysical Chemistry, New York: Pergamon Press, 1961, pp. 109-151) found that thymidine when injected into the rat is incorporated into the cells undergoing mitosis which surround the taste buds, and that these labeled cells are found within the taste buds within 50 to 300 hours.

(21) Just as there is a distinction between the pharmacist who prepares drugs and the doctor who administers them and the pharmacologist who studies them, so the term 'pedagogist' is introduced to distinguish between the pedagogist who studies teaching and the pedagogue who teaches (preparation and administration). Distinctions, such as these, are crucial to the notion and further emergence of a discipline or study of education apart from teaching as a profession.

(22) Once again a substitute term is offered, i.e. 'educatotypology.'

(23) Norman D. Bowers in "Meaningful Learning and Retention: Task and Method Variables" (Review of Educational Research, Vol. 31, 1961, pp. 522-534) sorts out a task variable and a method variable. 'The task variable' is defined as variability stemming from materials, and is taken to implicate only student behavior. 'The method variable' is defined as variability stemming from the procedures used by the teacher, and is taken to implicate only teacher behavior. We suggest that this sorting out is confusing, since student behavior surely is involved in procedures and teacher behavior usually is involved in materials.

(24) Setting aside the neglect of coalitive synergism in the experimentation of pedagogists, most of their experimentation is still suspect simply on the grounds of inadequate measurement of variables. In fact, the variables themselves are not clear, since the dimensions of specification of content and method are vague. Specification of the value of content or method is no small task. Assuming that a taxonomy of content and of method has been developed, the task of developing measures would still require doing. But then the educational scientist could take a clue from the other behavioral scientists and engage in more modest experimentation which often appears to border on the trivial. Appearance is taken to be reality, particularly by those impatient to get on with the task of controlling the educative process. Since most "educational scientists" are reformers, it is difficult to be modest. Could this be rooted in a failure to distinguish between the discipline or study of education and the profession or doing of education?

(25) In theorizing about education, we are not concerned to decide the value issue, and so close off theory in terms of a given philosophy of education. In other words, we shall not decide on one or more objectives of education, wanted effects, and theorize about the relation between teaching and those effects. As theoreticians, however, we are concerned about possibilities with respect to the value issue. A careful analysis of such possibilities would be the taxonomy called for. There is no doubt that such an analysis involves a high degree of philosophical sophistication; although more is required, since societal demands and other environmental considerations along with genetic considerations are of importance in relation to such possibilities.

(26) "Psychoanalysis and the Unity of Science," in Proc. Amer. Acad. Sci., Vol. 80, 1954, pp. 271-350.

(27) D. C. McCelland, Personality, New York: Dryden Press, 1951.

(28) D. C. McCelland, "An Integrative Approach," in Psychology of Personality, ed. by J. S. McCary, New York: Grove Press Inc., 1956, p. 338.

(29) See George S. Klein, "Issues and Paradoxes in Perception-Motivation Research," in Psychology of Personality, op. cit., pp. 123-199 for a discussion of such schemas.

(30) "Methods of Teaching," in Encyclopedia of Educational Research, ed. by Chester W. Harris, New York: The MacMillan Company, 1960, p. 850.

(31) Taxonomy of Educational Objectives, New York: Longmans, Green and Co., First edition, reprinted, 1960, p. 27.

(32) Chester W. Harris, "Review of This Issue," in Review of Educational Research, Vol. 32, 1962, p. 105.

(33) Jerome S. Bruner, The Process of Education, Cambridge, Mass.: Harvard University Press, 1960.

(34) B. Othanel Smith, "Critical Thinking," in Recent Research and Developments and Their Implications for Teacher Education, Thirteenth Yearbook, American Association of Colleges for Teacher Education, Washington, D.C.: the Association, a department of the National Education Association, 1960, pp. 84-96.

(35) Harold O. Taylor, "A Comparison of the Effectiveness of a Lecture Method and a Small-Group Discussion Method of Teaching High School Biology," in Science Education, Vol. 43, 1959, p. 446.

(36) Lawrence Siegel, "The Instructional Gestalt: A Conceptual Framework," in Teachers College Record, Vol. 62, 1960, pp. 202-213.

(37) Mary J. Miller, "Reading Readiness for a Blind Child in Public School," in Exceptional Children, Vol. 26, 1959, pp. 123-125.

(38) James G. Gallagher and Leonard J. Lucito, "Intellectual Patterns of Gifted Compared with Average and Retarded," in Exceptional Children, Vol. 27, 1961, pp. 479-482.

(39) David P. Ausubel and Elias Blake, Jr., "Proactive Inhibition in the Forgetting of Meaningful School Material," in Journal of Educational Research, Vol. 52, 1958, pp. 145-149.

(40) David P. Ausubel, "The Use of Advance Organizers in the Learning and Retention of Meaningful Verbal Material," in Journal of Educational Psychology, Vol. 51, 1960, pp. 267-272.

AN EDUCATIONAL THEORY MODEL:
QUANTUM THEORY*

by George S. Maccia
and G. William Reynolds

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I. INTRODUCTION

> An atom must have a stability which presents features quite foreign to a mechanical theory. (Neils Bohr)

If, as Bohr states, analogies drawn from descriptions of actions of a machine are not appropriate for conceptualizing the structure of an atom, it seems evident that attempts to conceptualize the structure of human learning through classical mechanical principles may be equally inappropriate. That we have been using, at least, formal models drawn from classical mechanical theory is suggested by our application of continuous functions and an assumption of equal probability in our efforts to quantify human behavior. A fundamental difficulty connected with such an approach will emerge if Newton's laws are taken as an educational theory model.

Newtonian Mechanics

Law I: Every particle persists in a state of rest or of uniform motion in a straight line unless compelled by an external force to change that state. According to this law, a particle moving in empty space with no field of force acting on the particle will follow a straight path in any direction.

Law II: The acceleration of a given particle is proportional to the force causing it. This second law requires that the velocity of the particle may have any value from 0 to ∞.

Under the conditions of the first and second laws, a line characterizing the path of a particle will be continuous, and the path of the particle at any instance will be a straight line. Figure 1 characterizes such motion in 3-dimensional space.

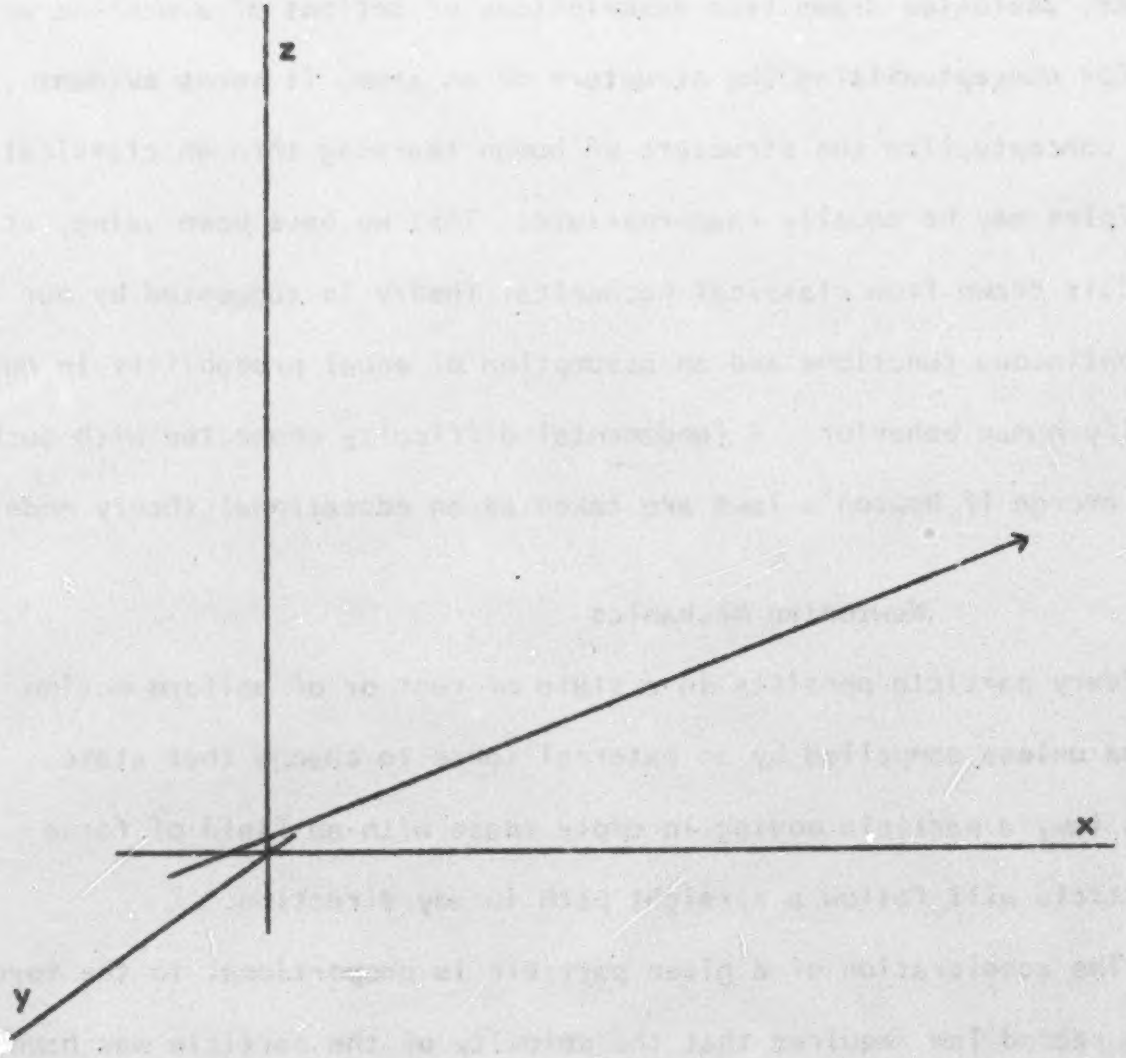


Figure 1. Path of a Moving Particle

Law III: For every force, there is an equal and opposite force. If the particle were enclosed, it would rebound off the walls of the enclosure in a direction opposite to its direction prior to rebound. If the collision does not result in energy loss, the particle will rebound back and forth along the same path. If the path and velocity of the particle is not known, then, under the conditions of the third law, any velocity or path may be considered to be equally probable.

Mechanical Theory of Teaching-learning

Law I: Every person persists in a state of behavior unless compelled by an external influence to change that behavior.

Teaching-learning Corollary I: Every student persists in not learning unless influenced by a teacher to learn. According to this corollary, influences other than the teacher's are assumed to act independently of the behavior of the student. Change in student behavior, therefore, is directly attributed to the influence of the teacher.

Law II: The rate of change in behavior is proportional to the influence causing it.

Teaching-learning Corollary II: The rate of change in student behavior (rate of learning) is proportional to the teaching causing it.

If this second corollary is considered with the first corollary, all learnings and all rates of learnings become possible. The relation between teaching and learning is seen as a unit ratio. Learning, thus, is described as a continuous and linear function. The linear programs of teaching machines rest upon such an assumption. Furthermore, the corollaries indicate that if the teaching influence is made great enough, continuous growth will take place in the direction set by the teacher. Under this view, the focus is upon what the teacher does rather than the behavior possible for the student. The genetic and environmental contexts are neglected.

Law III: For every influence, there is an equal change in behavior.

Teaching-learning Corollary III: For every teaching, there is an equal learning. From this corollary, the practice of standard testing based on normal population distribution seems to follow. Although all do not learn equally, the probability that the learning of one person is equal to that of another is assumed. The common practice of applying the same scale in grading all students would also follow from corollary III.

Upon inspection of the mechanical theory of teaching-learning, it becomes apparent that the theory overly simplifies the context of influence on students. Such simplification reduces the possibility for ascertaining the effects of a total influence configuration involving biological, psychological, and social dimensions.

If the perspective of quantum theory be substituted for that of Newtonian mechanics, such over-simplification might be eliminated. Quantum theory focuses on the context in which a particle moves, and characterizes particle motion in terms of its context. From such a perspective, the structure of the context of particle motion has been described to the degree that probabilities of action can be predicted in relation to the specific contexts in which that action occurs. Quantum theory, therefore, may offer a platform from which a contextual theory of education could be launched.

II. THE EDUCATIONAL THEORY MODEL (I)

Planck's Constant of Action

In attempting to explain, radiation of "black bodies," Planck asserted that the classical assumption of continuous emission and absorption of radiation by vibrating bodies had to be abandoned. In the classical view, there were infinitesimal amounts of action which when integrated over the entire vibration yield the action of the vibrator. If a body vibrates, the action for a complete vibration may be given by

$$A = \frac{E}{\nu}$$

where A is the action, E is the energy, and ν is the frequency. In Planck's view, the emission and absorption of radiation occur discontinuously.

Moreover, through Planck's assumption of discontinuity of emission and absorption, energy and action also came to be viewed as discontinuous rather than continuous processes. In quantizing action, Planck postulated that the action of the vibrator can only have the values o,h,2h,3h,...,nh, where h is a constant. Although Planck assumed that the action of a vibrator can have the value nh, subsequent modifications in quantum theory restrict the change in action by the amount h. With this later modification, the expression for discontinuous emission and absorption of energy became

$$E = h\nu$$

where E is the energy, h is the constant of action, and ν is the frequency of the vibrator.

Particle Motion Associated with Standing Waves

De Broglie utilized the expression for discontinuous emission and absorption of energy in postulating that standing waves are associated with particle motion in an enclosure (field of force) provided that there is no loss of energy when the particle rebounds from the walls of the enclosure. The energy and momentum of the particle are connected with the frequency and length of the wave by Planck's expression and the following relation postulated by De Broglie:

$$p = \frac{h}{\lambda}$$

where p is momentum, h is Planck's constant, and λ is wave length. This means that the wave exists only at the point the particle happens to occupy. It also was assumed that the wave front advances orthogonally to the trajectory of the particle. That is to say, the line of propagation of the wave is the directed line which characterizes the direction of the particle. For such conditions to hold, the phase of the wave must remain uniform over appropriate fixed surfaces (equiphase surfaces), and the phase at all points of a specified equiphase surface must be the same at any instant, although it varies rhythmically with time. Such rhythmic variation in the motion of the wave prohibits the continued existence of all possible waves associated with the motion of the particle, for waves reflected from the walls of the enclosure will superimpose upon each other so that interference effects occur. Some of the waves will be annihilated, others will be reinforced.

Figure 2 represents the associated waves of a particle in circular motion. In the Figure, the solid line represents reinforced waves, and, thus, waves which continue to exist. The dotted line represents waves which are in opposite phase to the reinforced waves, and, thus, waves which are annihilated. The waves that are reinforced do not advance; they are stationary; their position is fixed and their motion is like that of a vibrating string.

In order to employ Planck's expression, the motion of the wave must be that of a simple harmonic vibrator. If the wave associated with the motion of a particle is sinusodial, it vibrates as a simple harmonic vibrator. Standing waves generated by particle motion, however, may have less regular form than a sinusoidal wave. If the waves repeat at regular intervals, from Fourier's theorem on Fourier series the waves obtained may be viewed as results of superimpositions of a large number of sinus waves. The average of the superimposed waves--the fundamental of the waves--is a sinus wave. Unless the particles can escape from the enclosure, the only waves which will continue to exist are those which have certain definite frequencies.

The size and shape of the enclosure determine the energy of the state of the vibrating particles, and the boundary conditions of particle motion. Figure 3 represents a side view of a standing wave. The nodes--points at which the curve crosses the lind of propagation (denoted by 'A')--represent the boundary conditions. At the nodes little vibration occurs. If observed, the particle will appear to leap from crest to crest and vanish at the nodes. In other words, particle motion will be observed to be discontinuous.

The number and uniformity of the walls and surfaces in an enclosure affects the shape of the waves, the number of modes of vibration, and determine the degrees of freedom.

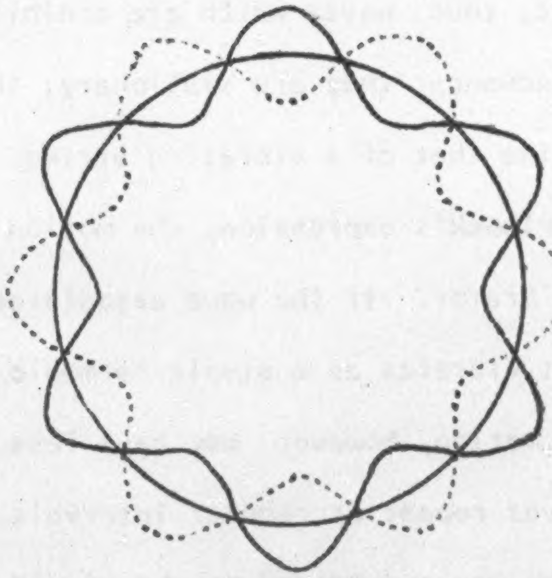


Figure 2. Waves Generated by Particle in Circular Motion

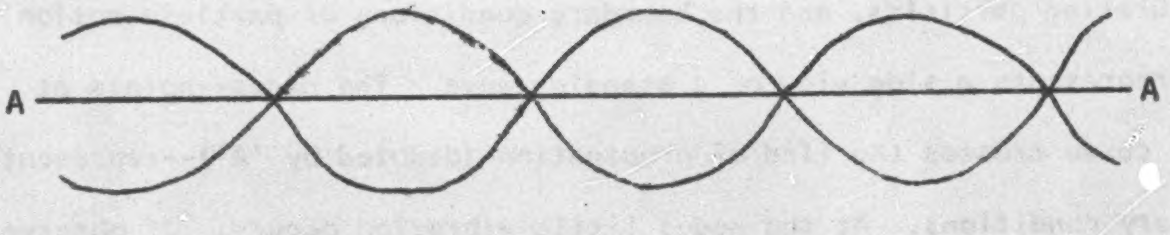


Figure 3. Standing Waves

The Solution of the Wave Function from the Schroedinger Equations

Time Dependent Wave Equation

A system containing n-degrees of freedom may be specified by a wave function which contains an arbitrary factor of modulus unity and is a single valued function of the coordinates and time. In general, it is a continuous complex function which is continuous in its first derivative.

$$\Psi = \Psi(q_1, q_2, \ldots q_n, t) \qquad 1.$$

where Ψ is the wave function, $q_1, q_2, \ldots, q_n$ are the coordinates, and t is the time. In order that the system be completely specified by the function, the following additional assumptions must be held:

1. the state of a system cannot be measured directly in any way;
2. certain physical quantities (observables) are measured;
3. observables are represented by operators which define the transformation in function space describing the system and which transform one wave function into another wave function;
4. operators are linear;
5. operators corresponding to observables possess a complete set of eigenfunctions (characteristic functions) and corresponding eigenvalues (characteristic values) ordered so that the real part of the first is less than the second, etc.;
6. any state with a finite norm can be expanded in a linear superimposition of these eigenvalues of the operator;
7. operators which represent observables are Hermitian or self-adjoint (eigenvalues of a Hermitian operator are real and the eigenfunctions are orthogonal); and
8. for every observable, there corresponds a Hermitian operator with a complete set of orthonormal eigenfunctions.

The solution of the wave function, Ψ, may be obtained from the Schroedinger equations:

$$ih\frac{\delta}{\delta t}(\Psi) = \left(\frac{-h^2}{2m}\nabla^2 + V\right)(\Psi) \qquad 2.$$

where

$$\left(\frac{-h^2}{2m}\nabla^2 + V\right)$$

is H, the Hamiltonian operator (2) on the function for the space variables being used (3).

It should be noted that equation 2 applies only if the Hamiltonian function describes the undisturbed system. If the system is undisturbed, the equation yields values which are particular solutions for the wave function. But since measurements of observables in a system disturb the system, the solution of the equation must be treated as probable rather than particular, i.e. the equation is degenerate and solutions for it must be in terms of probability distributions. Thus, for a given position (x,y,z), the value of Ψ is related to $\Psi \cdot \Psi^*$ (the probability of Ψ) where Ψ^* is the complex conjugate of Ψ. Therefore, a complete set of solutions in the region specified by the boundary conditions on the system may be given by

$$\Psi = \sum_n c_n \Psi_n \quad c_n < 1 \qquad 3.$$

In the equation, C_n is the normalization constant for each individual state of the system. (4) The probability disbribution for the wave function is given by

$$P = \sum \left| c_n \right|^2 \qquad 4.$$

The physical meaning of equation 4 is that a particle is either in one stationary state or another. That is to say for every eigenvalue, C_n, there are n^2 eigenfunctions or modes of displacement, Ψ ... This degeneracy results from the superimposition of waves with the same frequency but with different amplitudes and directions. In obtaining probabilities, an expectation value for the observable is defined. This value is obtained by calculating the average value which is found by repeatedly measuring the observable always starting the system in a particular state. When the mean square deviation of the observable is zero, a necessary and sufficient condition for the system to be an eigenvalue of the operator is indicated.

Time Independent Wave Equation

When V is not a function of time, Ψ may be expressed by

$$\Psi = \left(\Psi_{(T)} \right) \left(\phi_{(t)} \right) \qquad 5.$$

This expression holds when $\Psi_{(T)}$ may be considered a function of space variables only, and when $\phi_{(t)}$ is a function of time only. In the equation, T is a volume element of space and ϕ is a function representing the state of a system.

If equation 2 is divided by equation 5 the following equation is obtained:

$$\frac{ih}{\phi_{(t)}} \frac{\delta(\phi_{(t)})}{\delta t} = \frac{1}{\Psi_{(T)}} \left(\frac{-h^2}{2m} \nabla^2 (\Psi) + V_{(T)} (\Psi) \right) \qquad 6.$$

Since equation 6 contains different variables equal to each other which do not have any of their parameters in common, the expressions on both sides of the equation must be equal to the same constant. That constant is designated as energy, E. If the left side of equation 6 is set equal to E and solved for $\phi_{(t)}$, the following equation is obtained:

$$i h \frac{d\phi_{(t)}}{\phi_{(t)}} = E\,dt$$

and the following equation is derived:

$$\phi = K e^{-\frac{iE}{h}t}$$

In the equation K is the constant of integration which represents the initial condition of the function. If the right side of equation 6 is placed equal to E and solved for $\Psi_{(T)}$, the following equation is obtained:

$$\left(\frac{-h^2}{2m}\nabla^2 + V\right)\Psi = E\Psi \qquad 7a.$$

and the following equation is derived:

$$\left(\nabla^2 + (E - V)\right)\frac{2m}{h^2}\Psi = 0 \qquad 7b.$$

If equation 7b can be solved, then Ψ represents the energy sets in the system being investigated and all information concerning the system can be derived from Ψ.

Examples of Solution

Equation 7b will be used to solve two special cases of particle motion.

Case 1: The application of the Schroedinger time independent equation to 1-dimensional motion of a system within an enclosure of infinite potential is solvable. The conditions specifying this case are that there is only one space coordinate and one degree of freedom. When x meets the conditions that $0 \leqslant x \leqslant a$, the potential energy, ∇, is 0. When $0 > x > a$, the potential energy, ∇, is ∞.

Figure 4 characterizes the special case defined. The states, E_1, E_2, and E_3, are indicated in the Figure. It should be noted that, when the system is in state E_1, the boundaries are the walls of the enclosure and the wave associated with the particle has only one crest; when the system is in state E_2, the wave has three nodes and two crests; and when the system is in the state E_3, the wave has four nodes and three crests. In general, the number of crests in such associated waves is one less than the number of nodes or boundary conditions.

Under the conditions of this special case, the Schroedinger equation 7b reduces to either 8a or 8b:

$$\frac{-h^2}{2m}\frac{d^2(\Psi)}{dx^2} + V\Psi = E\Psi \qquad 8a.$$

$$\frac{h^2}{2m}\frac{d^2(\Psi)}{dx^2} + (E - V)\Psi = 0 \qquad 8b.$$

The solution of this differential equation is as follows:

$$\Psi = Ae^{i\alpha x} + Be^{-i\alpha x} \qquad 9.$$

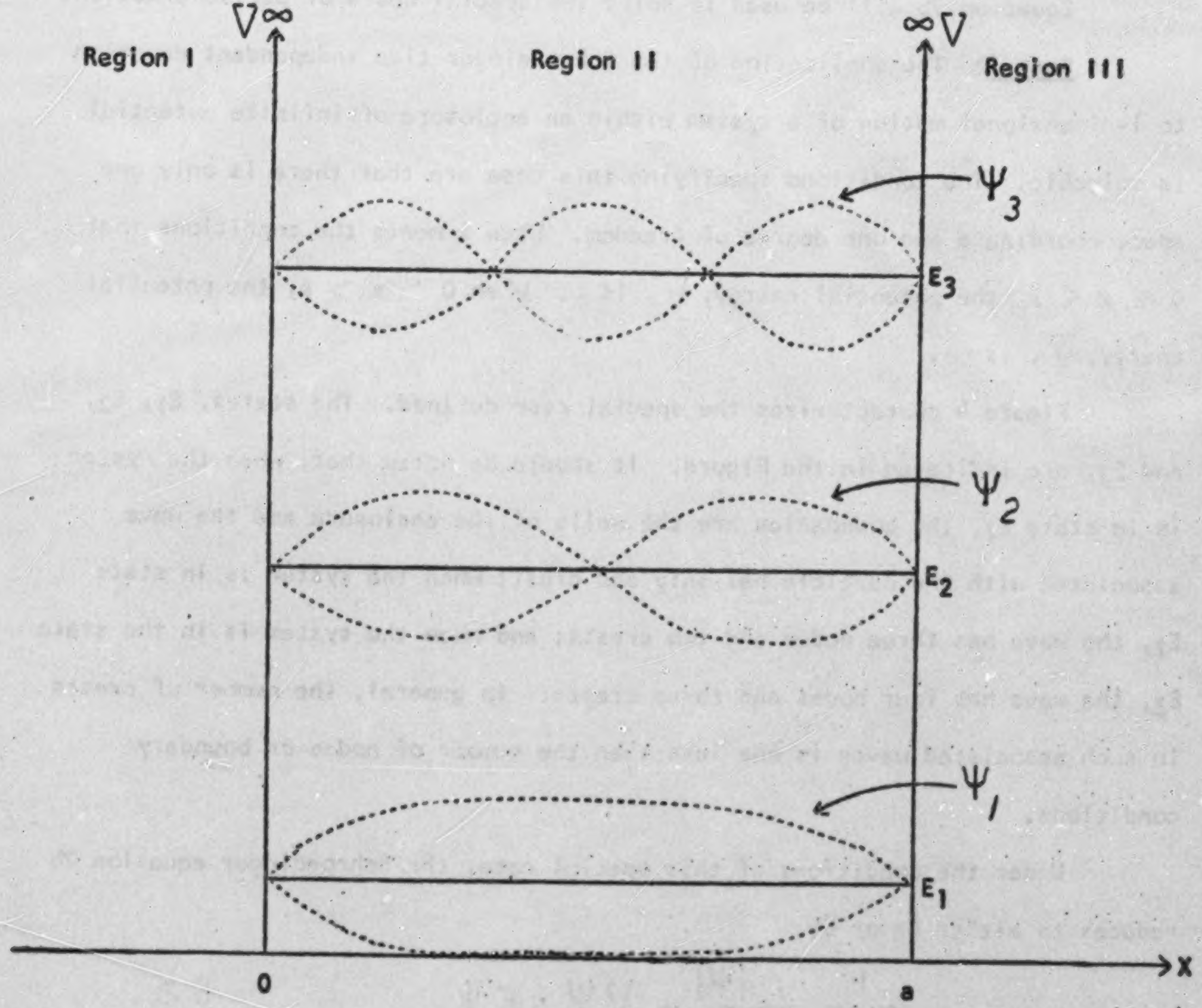

V∞
∞V
Region I
Region II
Region III
Ψ3
E3
Ψ2
E2
Ψ1
E1
0
a
X

Figure 4. Case I

In equation 9, A and B are any constants compatible with the boundary conditions, and

$$\alpha = \sqrt{\frac{2m|E-V|}{h^2}}$$

In general, the amplitude function of the states (E_1, E_2, E_3) is the sum of the amplitudes in each state:

$$\Psi_T = \Psi_1 + \Psi_2 + \Psi_3 \qquad 10.$$

Since Regions I and III are outside the enclosure and the particle is confined within the enclosure, in Regions I and III, Ψ is 0. In Region II:

$$\Psi = C \sin \alpha x \qquad 11.$$

If boundary conditions are applied in Region II so

$$V = 0, \ \alpha = \frac{n\pi}{a}, \quad E_n = \frac{h^2 n^2 \pi^2}{4ma^2}$$

it follows that

$$\Psi_n = \frac{1}{\sqrt{a}} \sin \frac{n\pi}{a} x, \quad (n = 1, 2, 3, \cdots) \qquad 12. [5]$$

The amplitude function Ψ_n of the states E_n is the sum of the amplitudes in each state:

$$\Psi_n = \Psi_1 + \Psi_2 + \Psi_3 \cdots$$

Case II: Figure 5 illustrates Case II which represents the solution of Schroedinger equations for a particle moving in two dimensions in an enclosure with infinite potentials. If $0 \leqslant x \leqslant a$, V_X is 0. If $0 > x > a$, V_X is ∞. If $0 \leqslant y \leqslant b$, V_Y is 0. If $0 > y > b$, V_Y is ∞. The total potential of the enclosure, V, is a function of the potentials for x and y:

$$V = V_X + V_Y$$

In this case, since there are two space coordinates, there are two degrees of freedom.

The Schroedinger equation 7b

$$\left(\nabla^2 + (E - V)\right)\frac{2m}{h^2}\Psi = 0$$

under the conditions of Case II becomes

$$\frac{-h^2}{2m}\left(\frac{\delta^2(\Psi)}{\delta x^2} + \frac{\delta^2(\Psi)}{\delta y^2}\right) + \left(E - (V_X + V_Y)\right)\Psi = 0 \qquad 13.$$

Equation 13 must be solved in each of the four regions which bound the plane having the coordinates, 00, 0a, ab, and 0b, as well as in the region enclosed by the plane. The solution for the equation is either 14 or 15. When

$$\alpha = \sqrt{\frac{2mE}{h^2}}\ , \ \beta = \sqrt{\frac{2mE}{h^2}}\ , \ \alpha a = n\pi\ , \ \alpha b = n\pi$$

$$(n = 1, 2, 3 \cdots)$$

$$\Psi_n = D\,\mathrm{SIN}\,\alpha x\ \mathrm{SIN}\,\beta y \qquad 14.$$

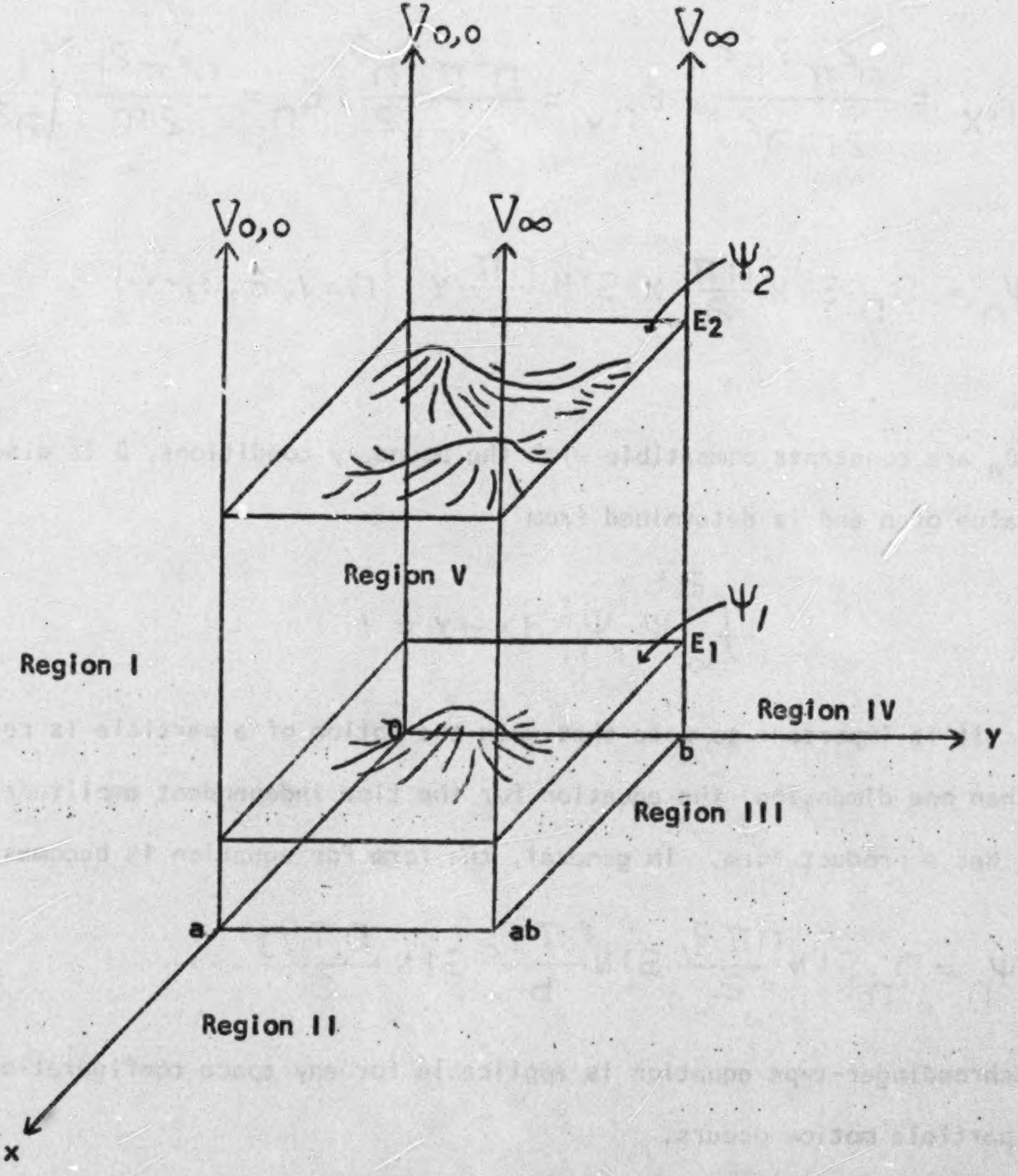

$V_{o,o}$
V_∞
$V_{o,o}$
V_∞
Ψ_2
E_2
Region V
Ψ_1
E_1
Region I
Region IV
0
b
y
Region III
a
ab
Region II
x

Figure 5. Case II

Ψ_2 is a region of 2 hills and 2 depressions related to the signs of the product function.

Ψ_1 is similar to a hill peaking in the central region of the enclosure plane.

when

$$E_{n_X} = \frac{n^2\pi^2h^2}{2ma^2},\ E_{n_Y} = \frac{n^2\pi^2h^2}{2mb^2},\ E_n = \frac{n^2\pi^2h^2}{2m}\left(\frac{1}{a^2}+\frac{1}{b^2}\right)$$

$$\Psi_n = D_n \text{SIN}\frac{n\pi}{a}X\ \text{SIN}\frac{n\pi}{b}Y,\ \left(n = 1, 2, 3, \cdots\right) \qquad 15.$$

Since D_n are constants compatible with the boundary conditions, D is discrete for each value of n and is determined from

$$\int_{\infty}^{ab} \Psi_n\Psi_n^* \, dX\, dY = 1$$

It is important to note that when the motion of a particle is related to more than one dimension, the equation for the time independent amplitude function, Ψ, has a product form. In general, the form for equation 15 becomes

$$\Psi_n = D_n \text{SIN}\frac{n\pi q_1}{a}\ \text{SIN}\frac{n\pi q_2}{b}\ \text{SIN}\frac{n\pi q_3}{c}\cdots \qquad 16.$$

This Schroedinger-type equation is applicable for any space configuration in which particle motion occurs.

Effects of a Perturbating Force

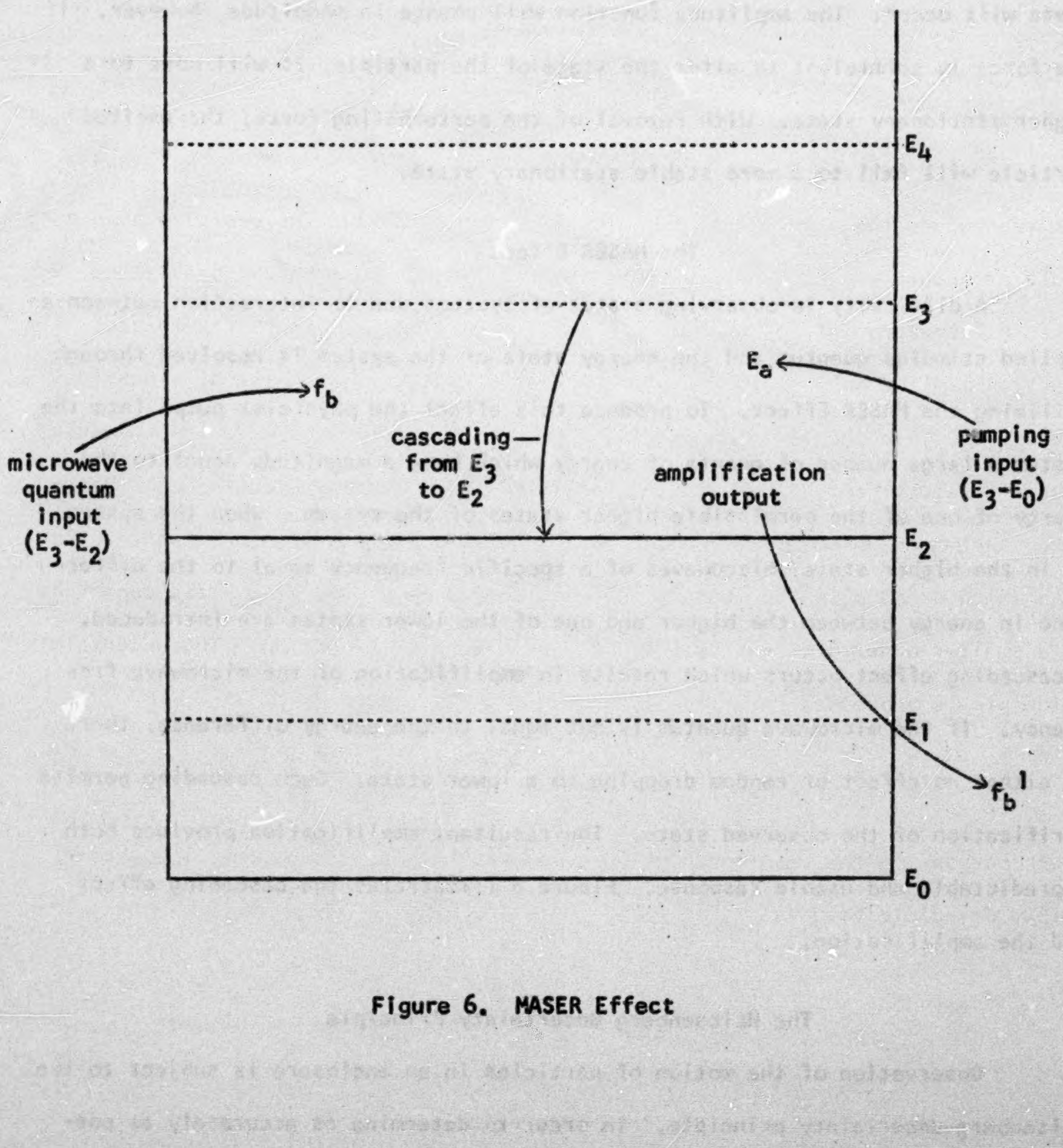
If a perturbating force acts on a particle in an enclosure, the motion of the particle will vary with the intensity and nature of the perturbating force. If the force is insufficient to alter the state of the particle, no change in state will occur. The amplitude function will change in magnitude, however. If the force is sufficient to alter the state of the particle, it will move to a higher stationary state. With removal of the perturbating force, the excited particle will fall to a more stable stationary state.

The MASER Effect

A difficulty in observing states of systems due to interaction between an applied stimulus quantum and the energy state of the system is resolved through utilizing the MASER Effect. To produce this effect the physicist pumps into the system a large number of quanta of energy which have a magnitude equal to the energy of one of the permissible higher states of the system. When the system is in the higher state, microwaves of a specific frequency equal to the difference in energy between the higher and one of the lower states are introduced. A cascading effect occurs which results in amplification of the microwave frequency. If the microwave quantum is not equal to the energy difference, there is either no effect or random dropping to a lower state. Such cascading permits verification of the observed state. The resultant amplification provides both a predictable and usable response. Fibure 6 illustrates the cascading effect and the amplification.

The Heinsenberg Uncertainty Principle

Observation of the motion of particles in an enclosure is subject to the Heisenberg uncertainty principle. In order to determine as accurately as possible position or momentum of a particle, the associated wave length must be determined as accurately as possible, since $P = \frac{h}{\lambda}$. In order to measure the



E_4
E_3
E_a
f_b
cascading— from E_3 to E_2
pumping input (E_3-E_0)
microwave quantum input (E_3-E_2)
amplification output
E_2
E_1
f_b^1
E_0

Figure 6. MASER Effect

wave length, λ, accurately, the wave train must be greatly extended. In the limiting case, it must be infinitely extended, if λ is to receive an absolute exact value. When λ receives an exact value, the position at which the particle will be found will be completely uncertain; for the probability for locating a particle at a certain point is $\Psi \cdot \Psi^*$. When the wave is infinitely extended, p has everywhere the same value, $\Psi \cdot \Psi^*$. In order to define the position of a particle as accurately as possible, the wave function Ψ must be chosen so that it differs from zero only at one given point. According to Fourier's theorem, a function limited to a small region can be produced by overlapping of sinusoidal waves. Thus, in the limiting case--the position defined--the wave lengths must take all values from 0 to ∞. Such conditions make the wave length and, therefore, the momentum completely uncertain. When Δ_q and Δ_p are the uncertainties with which q and p can be measured simultaneously, the product $\Delta_q \cdot \Delta_p$ cannot be of a smaller order of magnitude than Planck's quantum of action. The uncertainty principle is expressed formally as

$$\Delta_q \cdot \Delta_p \geqslant h \qquad 17.$$

When considering the relationships between energy changes and time, the uncertainty principle becomes

$$\Delta_t \cdot \Delta_E \geqslant h \qquad 18.$$

The Complementary Principle

The complementary principle asserts that no matter how accurate an apparatus may be, measurements more precise than those indicated by the uncertainty principle cannot be made. The principle typifies the fundamental limitations in descriptions of a minute particle system.

III. EDUCATIONAL THEORY

Constant of Behavior

The model suggests a theory of behavior in which behavior is viewed as rhythmical. However, this periodicity is expressible in terms of frequencies modified by a constant of behavior. This can be expressed as follows:

$$B = \square \beta$$

where B is behavior, $\square$ is a constant of behavior, and β is the frequency of behavior.

Quantification procedures which rely on integration of infinitesmals become inadequate. The magnitude of behavior does not vary continuously from 0 to some value taken as maximum or unity. It varies discontinuously. Behavior occurs in quantum fashion or appears only at certain magnitudes. That is to say, behavior can have only certain values. There are levels of behavior. Consequently, only certain stimulus magnitudes produce behavior.

In an educational context, it may be expected that student's behavior will appear only at certain values [all learning will be stepwise as in the case of auditory perception which Békésy reported to be observed by Brecher and which is illustrated in Figure 7 (6)] and not all values of teaching will produce learning. Teaching will have to assume certain magnitudes. Furthermore, either a constant of learning or of teaching may be determinable. The size of steps

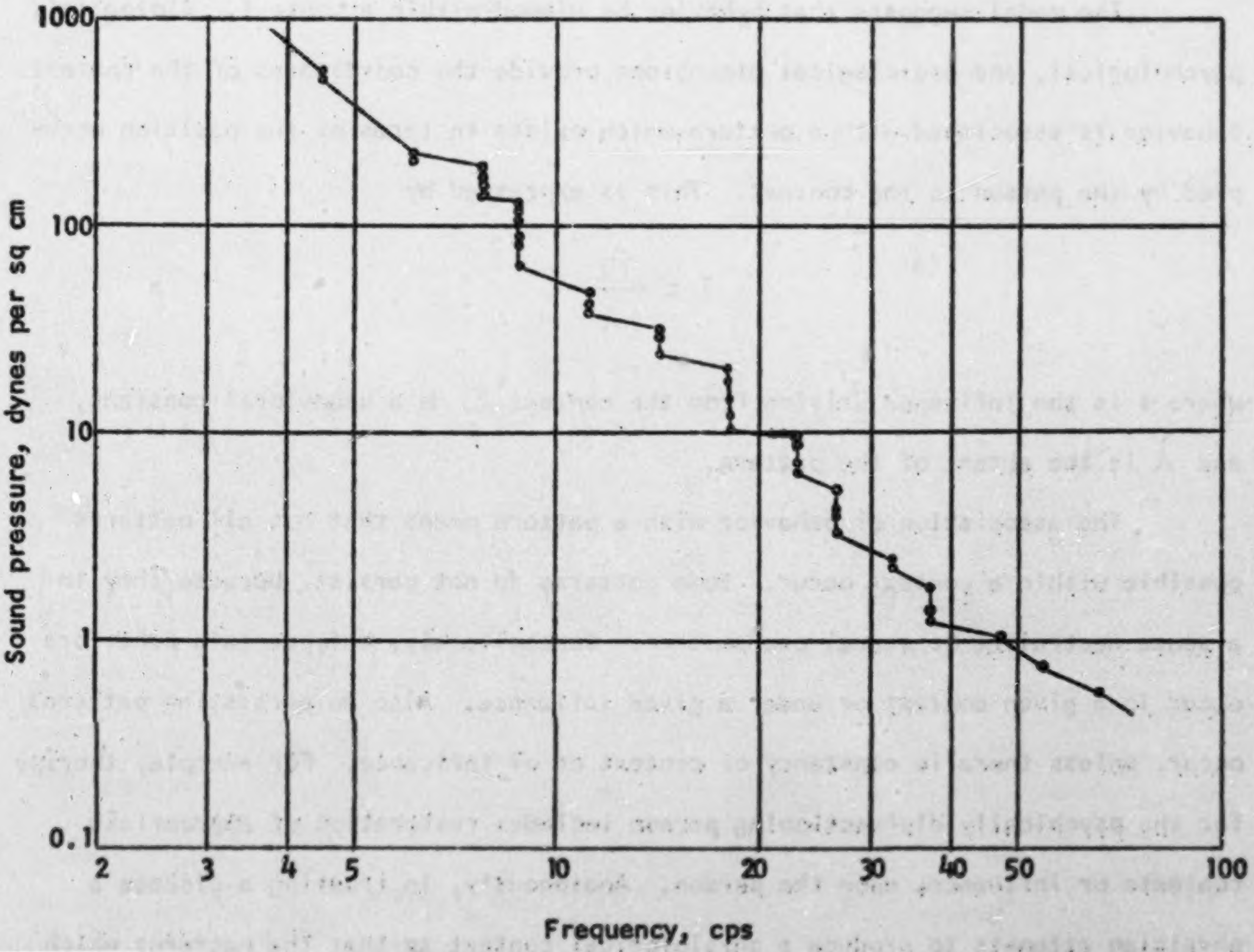


Figure 7. Steplike Form of the Threshold Curve at Low Frequencies

would follow. This would have significance for programming, machine or otherwise.

Behavior Associated with Patterns

The model suggests that behavior be viewed within a context. Biological, psychological, and sociological dimensions provide the coordinates of the context. Behavior is associated with a pattern which exists in terms of the position occupied by the person in the context. This is expressed by

$$I = \frac{\square}{\lambda}$$

Where I is the influence arising from the context, $\square$ is a behavioral constant, and λ is the extent of the pattern.

The association of behavior with a pattern means that not all patterns possible within a context occur. Some patterns do not persist, because they in a sense neutralize or cancel one another. Concomitantly, only certain behaviors occur in a given context or under a given influence. Also no persisting patterns occur, unless there is constancy of context or of influence. For example, therapy for the psychically disfunctioning person includes restoration of appropriate contexts or influences upon the person. Analogously, in treating a disease a physician attempts to produce a physiological context so that the patterns which are life persist.

Change in behavior demands a change in influence. The more stable a behavioral state is, the greater the influence will have to be to change it. Stability of a behavioral state increases with the time the related influence persists.

From the general behavioral theory, it follows that the specific context established in the classroom will determine possible student behaviors and their magnitudes. Influences are not simply restricted to those of the teacher, but arise out of the total classroom situation. What would be necessary is a taxonomy of classroom situations and the student behaviors sustained therein. Moreover, it would be of utmost importance to take into account the time factor in relation to influence. Increasing the stability of student behaviors could mitigate against utilization of one student behavior as a stage toward another student behavior.

The Solution of the Behavioral Pattern Function from Schroedinger Type Equations

Time Dependent Behavioral Pattern Equation

The behavior of a person which is in a context (which has n-degrees of freedom) may be expressed by a behavioral pattern function, Ψ

$$\Psi = \Psi\left(w_1, w_2, \cdots, w_n, t\right) \qquad 19.$$

where $w_1, w_2, \ldots, w_n$ are context variables and t is time. An operator for the behavioral pattern function, γ, may be expressed as follows:

$$\gamma = \gamma\left(I, Q\right)$$

where I is the influence and Q is the behavioral capacity. Assuming a Hamiltonian type operator, ∇^2, for the behavioral pattern function, the following equation may be stated:

$$\gamma = \left(-\Box^2 \cdot \nabla^2 + Q\right) \qquad 20.$$

In equation 20, $i\Box\nabla$ corresponds to I as an operator.

Not only does the model provide a perspective in which only certain behaviors (including student behaviors) which are permissible occur and in which changes in such stationary behavioral states involve movement to other stationary behavioral states, it also provides a perspective in which the average (fundamental) of the stationary behavioral pattern will be sinusoidal. The sinusoidal character of behavioral patterns is suggested too by the application of Fourier's analysis to biological rhythms wherein the "assemblage of sinus curves constitutes a perfect description of the average rhythm" (7). Assuming, then, behavioral patterns which are stationary and sinusoidal, they may be considered as produced by linear harmonic vibrators. Appropriately modified Schroedinger equations may provide first approximations of such magnitudes in human behavior:

$$i\Box\frac{\delta}{\delta t}\left|\Psi\right| = \left|-\Box^2\nabla^2 + Q\right|\Psi \qquad 21.$$

$$\Psi = \sum_n a_n \Psi \qquad 22.$$

Only if one assumed non-contextual behavior could these equations provide exact solutions. Since such an assumption runs counter to the theory, a probability distribution must be assumed which may be given by

$$P = \sum_n \left|a_n\right|^2 \qquad 23.$$

It follows, therefore, that equations which are soluable for behavior will not predict precisely which behavioral state or pattern a person will occupy for given values of behavioral states or behavioral change. It is suggested by the model that we cannot expect to determine one behavioral pattern as well as another for a given individual or group of individuals. We can predict only n-number of behavioral patterns one of which the individual or group will occupy. By employing an arbitrary factor of modulus unity, the probability of any given pattern will be less than one.

Time Independent Behavioral Pattern Equation

If we assume that behavioral capacity is not a function of time, the behavioral pattern may be written as a product of two functions:

$$\psi = \left(\psi_{(T)}\right)\left(U_{(t)}\right) \qquad 24.$$

where ψ is a function only of the behavioral context variables and U is a function only of time.

If equation 21 is divided by equation 24, the following expression is obtained:

$$\frac{i\Box}{U_{(t)}}\frac{\delta}{\delta t}\left(U_t\right) = \frac{1}{\psi_{(T)}}\left(-\Box^2\nabla^2 + Q\right)\psi \qquad 25.$$

By employing the argument in the model that both sides of this equation are equal to the same constant, and by assuming this constant, B, to be a behavioral unit related to an appropriate behavioral context, the following equation may be stated:

$$\frac{d}{U_{(t)}}\left(U_{(t)}\right) = \frac{B}{i\Box}dt \qquad 26.$$

which reduces to

$$u_t = Ce^{-i \frac{B}{\square} t} \qquad 27a.$$

or

$$\mathrm{Ln}\, U = -i \frac{B}{\square} t \qquad 27b.$$

In equation 27a, C is the constant of integration which represents the initial conditions and U is a function representing the behavioral state. The curve for equation 27 is shown in Figure 8. It should be noted that this curve has the same form as that of the Weber-Fechner equation derived by Lehmann:

$$E = b\,\mathrm{Ln}\left(1 + \frac{aJ}{C}\right) \qquad (8)$$

When the left side of equation 25 is set equal to the behavioral unit, the following equation is obtained

$$\frac{1}{\psi}\left(-\square^2 \nabla^2 + Q\right)\left(\psi\right) = B \qquad 28.$$

If both sides of equation 28 are multiplied by ψ, then

$$-\square^2 \nabla^2 \psi + Q\psi = B\psi$$

and

$$\square^2 \nabla^2 \psi + \left(B - Q\right)\psi = 0$$

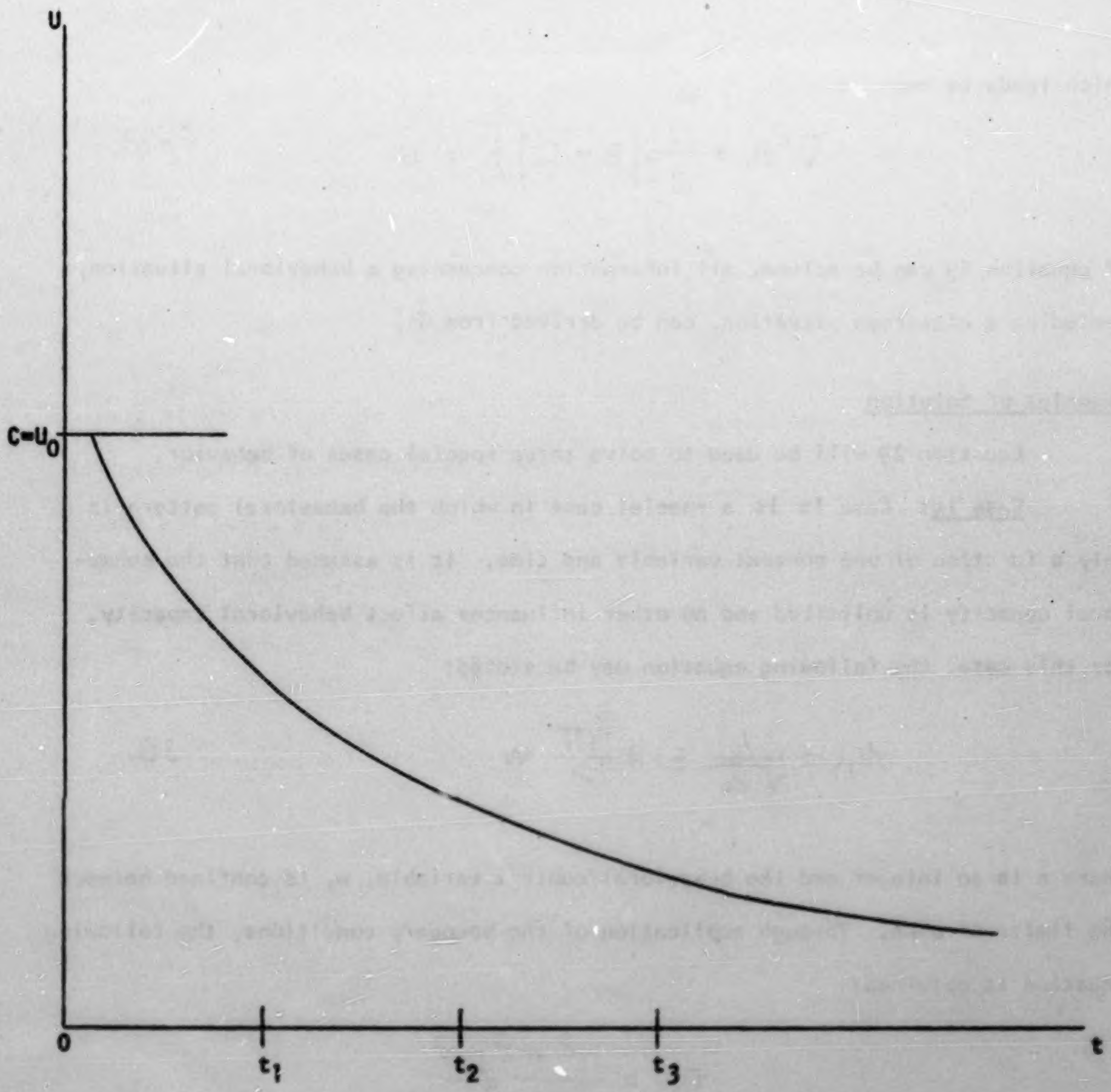


Figure 8. Change in Behavior as an Exponential Function

which leads to

$$\nabla^2 \psi + \frac{1}{\square^2}\left(B - Q\right)\psi = 0 \qquad 29.$$

If equation 29 can be solved, all information concerning a behavioral situation, including a classroom situation, can be derived from ψ.

Examples of Solution

Equation 29 will be used to solve three special cases of behavior.

Case Ia: Case Ia is a special case in which the behavioral pattern is only a function of one context variable and time. It is assumed that the behavioral capacity is unlimited and no other influences affect behavioral capacity. For this case, the following equation may be stated:

$$\psi_n = \frac{1}{\sqrt{a}} \sin \frac{n\pi}{a} w \qquad 30.$$

where n is an integer and the behavioral context variable, w, is confined between the limits of o→a. Through application of the boundary conditions, the following equation is obtained:

$$B_n = \frac{n^2 \pi^2 \square^2}{a^2}$$

B_n is quantized and particular values of B_n are obtained. In the equation n is an integer.

The equation for the behavioral pattern function for this case is

$$\psi = \sum_{n} C_n \left(u_0 e^{-i \frac{B}{\Box} nt} \right) \psi_n \qquad 31.$$

where C_n is the normalization constant for each behavioral state.

Referring once again to Figure 4 and substituting Q for V, B for E, ψ for Ψ, and w for x, the behavioral patterns for Case Ia are characterized. In Region II, it is assumed that the behavioral units, B, result from the influences taking place within the limits of the individual and his behavioral capacity. The limits of the individual are described by the behavioral context variable, w. These limits are defined as $0 \leq w \leq a$. It is assumed also that behavioral units are predictable, finite, and unique, and that

$$B_n = \Box \beta \qquad 32.$$

$$I_n = \frac{\Box}{\lambda_n} \qquad 33.$$

$$S = \beta_n \lambda_n \qquad 34.$$

where S symbolizes the level of motivation of the individual. Motivation is taken to be analogous to the constant of light, but it is to be noted that S will have different values depending upon the particular behavioral pattern.

If equations 32, 33, and 34 are combined, the following equations are obtained:

$$B_n = \square \frac{S}{\lambda_n} = I_n S \qquad 35.$$

The influence required to produce discrete values of behavior may be obtained through

$$I_n = \frac{n^2 \pi^2 \square^2}{a^2 S} \qquad 36.$$

Case Ib: Case Ib is the same as Case Ia in that the behavioral pattern is only a function of one context variable and time, but differs in that the behavioral capacity is assumed limited although no other influences are taken to affect it. This case is illustrated in Figure 9 which indicates that behavioral patterns will extend beyond the context. In Region II of that Figure, it is assumed that behavioral units resulting from influence on the individual take place within the limits of the individual and his behavioral capacity. The limits of the individual are described by the behavioral context variable w. These limits are defined as $-a \leq 0 \leq a$. No particular influences outside Region II will produce any specific behavior.

Under the conditions of Case Ib

$$\pitchfork_w = \pitchfork_1 + \pitchfork_2 + \pitchfork_3 \qquad 37.$$

and the equation

$$\square^2 \nabla^2 \pitchfork + \left(B - Q\right) \pitchfork = 0 \qquad 38.$$

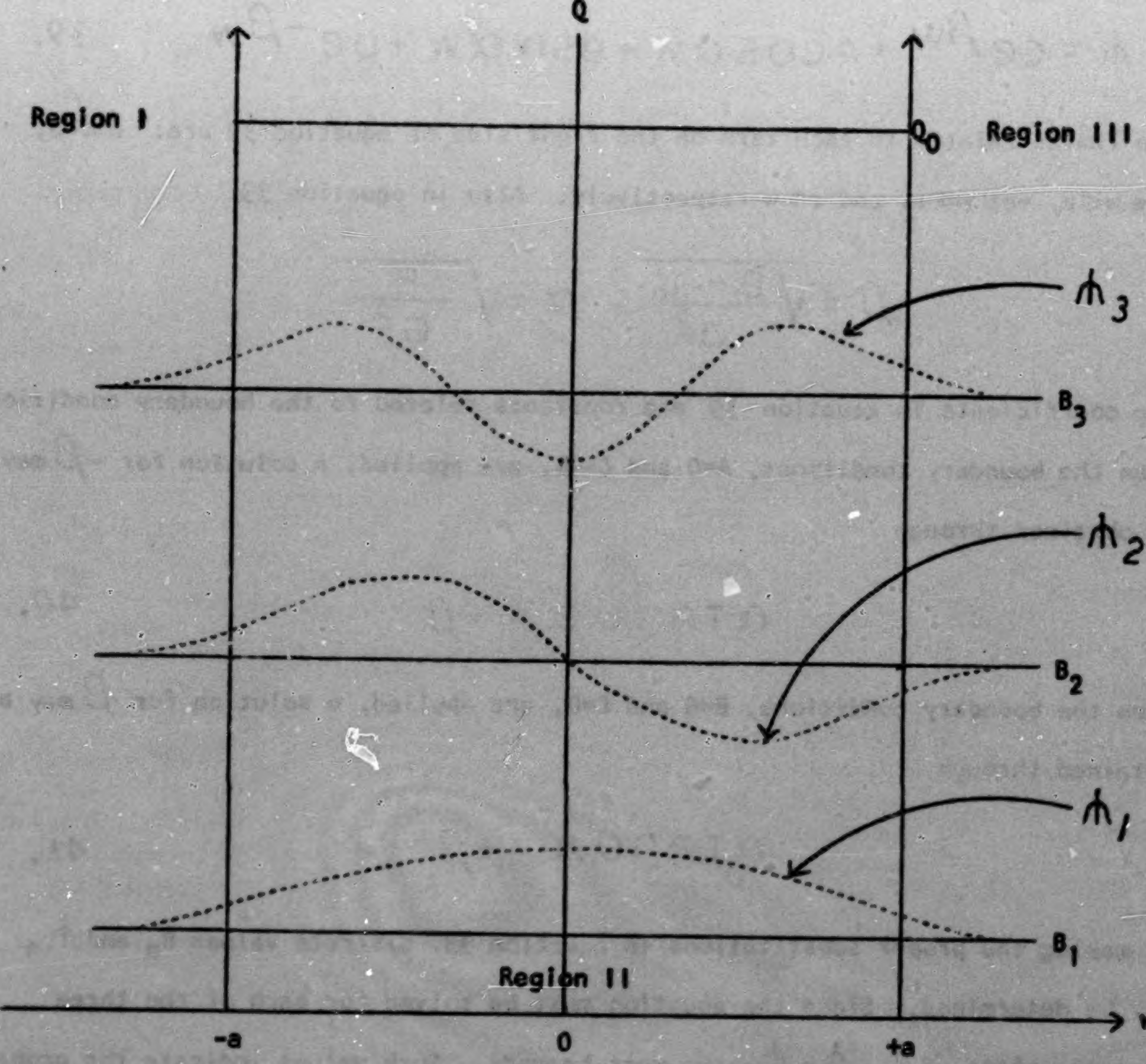

Q
Region I
Q0
Region III
ψ3
B3
ψ2
B2
ψ1
B1
Region II
-a
0
+a
w

Figure 9. Case Ib

the solution is

$$\psi = Ce^{\beta w} + A\cos\alpha w + B\sin\alpha w + De^{-\beta w} \qquad 39.$$

The limits related to each term on the right side of equation 39 are: $w \leq -a$, $-a \leq w \leq a$, $-a \leq w \leq a$, and $a \leq w$ respectively. Also in equation 39

$$\beta = \sqrt{\frac{B - Q_0}{\Box^2}}\ , \quad \alpha = \sqrt{\frac{B}{\Box^2}}$$

The coefficients in equation 39 are constants related to the boundary conditions. When the boundary conditions, $A=0$ and $C=-D$, are applied, a solution for $-\beta$ may be obtained through

$$\alpha \tan \alpha a = -\beta \qquad 40.$$

when the boundary conditions, $B=0$ and $C=D$, are applied, a solution for β may be obtained through

$$\alpha \tan \alpha a = +\beta \qquad 41.$$

By making the proper substitutions in equation 39, discrete values B_n and ψ_n may be determined. Since the equation must be solved for each of the three regions, plots of $\psi_1, \psi_2, \psi_3, \ldots$ must be made. Such values indicate the probability of finding influence in the forbidden areas. When B_n equals or is greater than Q_0, the behavior is purely random, continuous, and unpredictable.

Case II: Case II is a special case in which the behavioral pattern is a function of two behavioral context variables and the time. Also it is assumed that there is a finite limit on behavioral capacity and no other influences affect that capacity. As Figure 10 indicates, behavioral patterns will extend beyond the context, thereby requiring analysis in each of the five regions.

In Region V it is assumed that behavioral units resulting from influence on the individual take place within the limits of the individual and his behavioral capacity. The limits of the individual are described by the behavioral context variable, w. For w_1, these limits are defined as $0 \leq w_1 \leq a$, where

$$Q_{W_1} = Q_{o_{W_1}}$$

When $w_1 < 0$ and $w_1 > a$,

$$Q_{W_2} = 0$$

Limits for w_2 are defined as $0 \leq w_2 \leq b$, where

$$Q_{W_2} = Q_{o_{W_2}}$$

When $w_2 < 0$ and $w_2 > a$

$$Q_{W_1} = 0$$

It is assumed further that behavior takes place in Region II and in no other, and that no particular influences outside Region V will produce any specific behavior.

In obtaining solutions for Case II the Schroedinger type equation

$$\square^2 \nabla^2 \pitchfork + \left| B - Q \right| \pitchfork = 0$$

is employed. When

$$Q = Q_{\left| W_1 W_2 \right|}$$

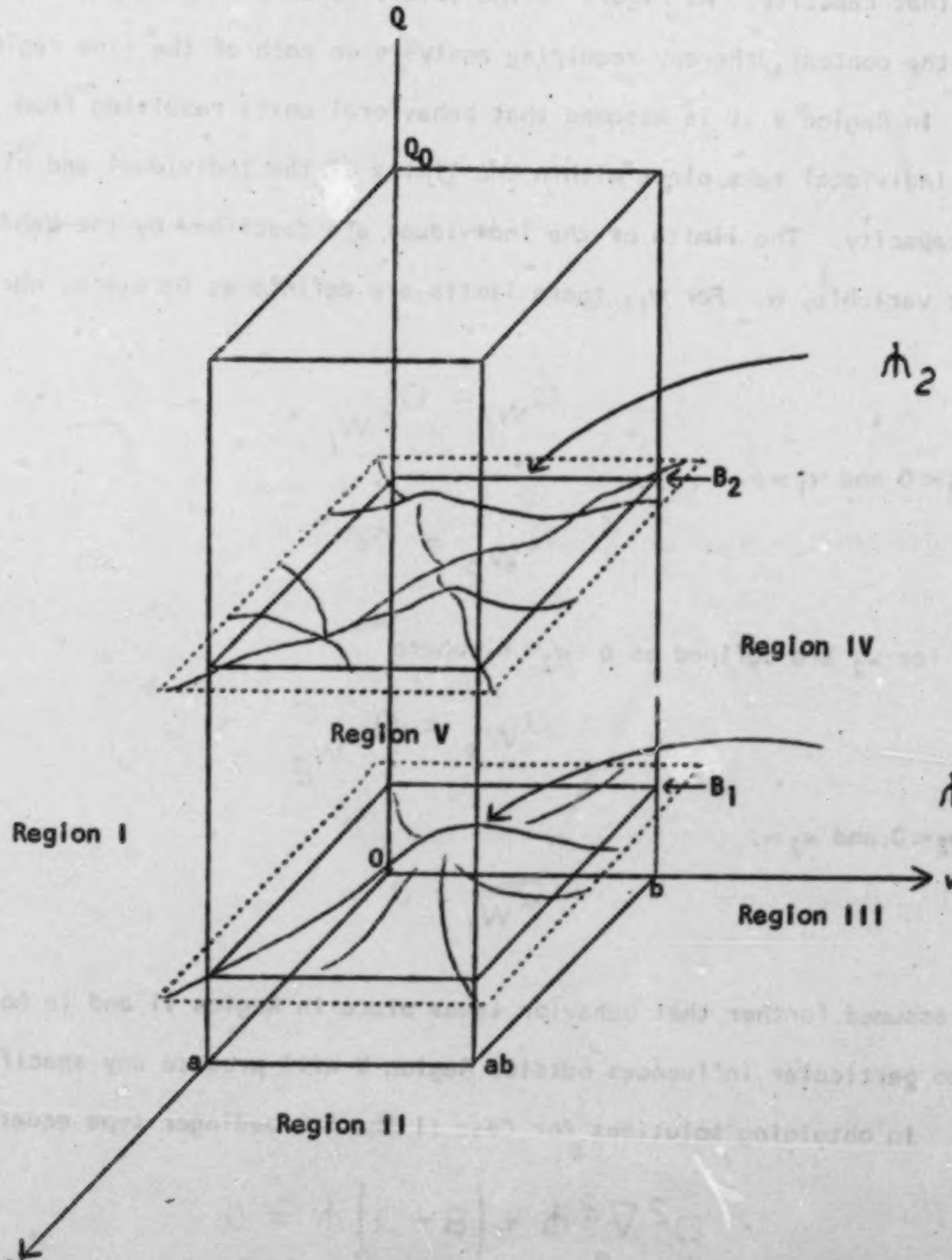

Q
Q_0
$\hbar_2$
B_2
Region IV
Region V
B_1
$\hbar_1$
Region I
O
b
w_2
Region III
a
ab
Region II
w_1

Figure 10. Case II

this equation reduces to

$$\frac{\delta^2 \psi}{\delta w_1^2} + \frac{\delta^2 \psi}{\delta w_2^2} + \left(B - \left(Q_{w_1} + Q_{w_2}\right)\right)\psi = 0 \qquad 42.$$

Equation 42 is solvable in the form

$$\psi_n = A_n e^{i\left(\gamma w_1 + \eta w_2\right)} + B_n \sin \alpha w_1 \sin \beta w_2 + C_n e^{-i\left(\gamma w_1 + \eta w_2\right)} \qquad 43.$$

The limits related to each term on the right side of equation 43 are: $w_1 < 0$, $w_2 < 0$; $0 \leq w_1 \leq a$, $0 \leq w_2 \leq b$; and $w_1 > a$, $w_2 > b$ respectively. Also in equation 43

$$\gamma = \sqrt{\frac{B_{w_1} - Q_{\circ w_1}}{\square^2}} \, , \quad \eta = \sqrt{\frac{B_{w_2} - Q_{\circ w_2}}{\square^2}}$$

The coefficients in equation 43 are constants related to the boundary conditions. When the boundary conditions, $0 \leq w_1 \leq a$, are applied

$$\alpha = \frac{n\pi}{a}, \quad \alpha^2 = \frac{B}{\square^2}, \quad \left(n = 1, 2, 3, \ldots\right)$$

Therefore,

$$B_{n w_1} = \frac{\square^2 n^2 \pi^2}{a^2} \qquad 44.$$

When the boundary conditions, $0 \leq w_2 \leq b$, are applied

$$\beta = \frac{n\pi}{b}, \quad \beta^2 = \frac{B}{\square^2}, \; (n = 1,2,3, \cdots)$$

Therefore,

$$B_{n_{w_2}} = \frac{\square^2 n^2 \pi^2}{b^2} \qquad 45.$$

Combining equations 44 and 45

$$B_n = B_{n_{w_1}} + B_{n_{w_2}} = \square^2 n^2 \pi^2 \left(\frac{1}{a^2} + \frac{1}{b^2} \right)$$

which yields the solutions for n behaviors permissible in the two-dimensional behavioral context.

The Schroedinger type equation derived for Case 3 suggests that in behavioral measurement more complex taxonomies are required. Characterizations of behavior must be in terms of subsets of behavioral patterns permissible in a given behavioral context. In attempting to develop such taxonomies, the mean of repeated measures of kinds of behavior given in our present taxonomies might be viewed as behavioral spectra. From such spectra, it might be possible to calculate behavioral patterns related to specific behavioral contexts. Implications for characterizing student behavior, educational measurement, follow.

Objections might arise on the grounds that a person might deliberately withold behavioral change. However, since a context is involved, shifts in some of the measures would occur which would enable classification.

Behavioral traits, suitably measured, might provide values for behavioral capacity. For example, through the use of teaching machines, behavioral constants for specific student behavioral contexts might be obtained. Such data would enable predictions of behavioral patterns and behavioral change through Schroedinger type equations. Also computers could be used to provide constant student behavioral contexts from which empirical measures of student behavioral patterns might be obtained. Such measures then might serve in testing theoretical predictions obtained through the equations.

Effects of a Disturbing Influence

If a disturbing influence acts upon an individual who, of course, is in a given context, his behavior will vary with the intensity and nature of the influence. If the influence is insufficient to alter his behavioral state, no change in behavior will occur. If it is sufficient, change to another state will occur. With removal of the disturbing influence, the stimulated individual will return to a more stable behavioral state.

Teaching, then, requires stimulation of the individual to the degree that a change in behavioral state occurs. In order for that change in behavior to continue, the teaching influence must persist. The individual must internalize the teaching. Measures of the learned behaviors which persist will enable evaluations of the intensity of teachings. It may be expected that teachings which reinforce influences in specific behavioral contexts will be more intensive than those which do not reinforce such influences.

Ideal teaching influences defined through the use of teaching machines, computers, television and the like might serve as standards in terms of which the effectiveness of other teachings might be determined. Through such means, it might be possible to devise teaching intensity scales for given student behavioral contexts, thereby allowing more rigorous evaluations of teaching effectiveness.

BIDI Effect (Behavioral Intensification Through Distributing Influence)

The MASER effect employed by physicists suggests an approach in influencing which may result in greater stimulation of the individual and so intensification of behavior. If an influence were maintained at one of the higher levels of behavior permissible for a given context and a distributing influence introduced appropriate to one of the lower levels, the stimulation of the individuals at this lower level may be increased or his behavioral state intensified. For example, in teaching problem solving, if the teaching influence is maintained at a level beyond the necessary intermediate steps required in the possible learning and a disturbing teaching influence is introduced at one of the intermediate steps, then learning at that step will be intensified. Teaching procedures patterned after such games as Twenty Questions may offer conditions for such intensification of student behavior.

Inherent Uncertainty in Observation of Behavior

It has long been understood that exact measurements of behavior are limited by subjective elements in observation and in the precision of the instruments used. Every measurement has an associated probable error. The model suggests also that uncertainty of either influence or behavior, and not both, will obtain. Consequently, simultaneous measures cannot yield absolute exact values. It follows that educational measurement is inherently probabilistic. The more accurate our knowledge of the effect of teaching the less accurate our knowledge of a student's achievement.

The Complementary Principle

The complementary principle suggests that measures of behavior by means of apparatus can be no more accurate than the difference between one behavior and another required by the behavioral constant associated with the behavior being observed. Hence, improvement of apparatus will not result in increasing the accuracy of measurement beyond certain limits, which limits are determined by the behavioral constant. The implications for educational measurement are obvious.

Analysis of Group Behavior

Although nothing was stated in the model related to motion of particle aggregates in an enclosure, quantum theory suggests that classical statistical procedures would not be appropriate in the analysis of group behavior. Equal probability may not be assumed. If a behavioral pattern of a group is obtained by adding N! fundamental ones, that pattern is symmetric and solutions must be obtained through a Boseian type statistics. If a behavioral pattern of a group is obtained by appropriate additions and subtractions of fundamental ones, that pattern is antisymmetric and solutions must be obtained through a Fermian type statistics.

IV. SIGNIFICANCE OF QUANTUM THEORY

A correspondence principle similar to that in quantum theory cannot be said to hold for the educational theory presented. There is no single, unified, and tested theory of behavior or of behavior in the school setting. Consequently, for the educational theory there is no relatively complete body of empirical knowledge with which solutions of the equations in the theory must correspond. Nevertheless, there are empirical findings which indicate relevance of the educational theory devised from a quantum theory model.

Békésy's discussion of Fechner's law (9) points to discontinuity in human perception. The law relates increase in stimulus magnitude with increase in sensory intensity. Fechner observed that the stimulus intensity had to be altered by a certain amount in order to produce a just noticeable change of sensory magnitude. He suggested, therefore, that changes in sensory magnitude occur in a quantum fashion. Fechner also assumed a constant of sensory behavior. According to him, quantum changes are equal in magnitude throughout the entire range of sensation, and the smallest quantum of sensation cannot be reduced through practice or attention.

Certain results of Pavlov's experiments with dogs suggest quantum change in conditioning phenomena. Discontinuity in conditioning is alluded to in the following statement of Pavlov:

> For every one of our animals . . . there is a maximum stimulus, a limit of harmless functional strain, beyond which begins the intervention of inhibition . . . thus distorting the usual rule of the relationship between the magnitude of the effect and the intensity of excitation; a strong stimulus may produce an equal and even a smaller effect than a weak one . . . . (10)

A constant of behavior assumed by Fechner and alluded to by Pavlov is again suggested in Wilder's Law of Initial Value (LIV). Wilder found in 80% of his experiments that the higher the initial value of a measured function, the lower is the tendency of the system to respond to further stimuli and the greater its tendency to decrease in responding to inhibitory stimuli; the highest as well as the lowest values tend to result in a reversal of action. (11) In their analysis of Wilder's law, Block and Bridger call attention to the fact that stimulus levels for responses remain constant over repeated stimulations which may even be years apart. (12)

In support of their theory of neural quantum in discrimination of loudness and pitch, Stevens, Morgan, and Volkman presented experimental evidence to show that there is a distinct minimal level of loudness which caused a perceptual sensation of sound. They also showed that there is a distinct minimal frequency variation necessary for perceptual sensation. (13)

Suppes and Ginsberg suggest a constant of behavior in concept formation in children. They assert that a basic assumption of a simple all-or-none conditioning model is the probability that a correct response remains constant over the trials before conditioning. (14)

It is unnecessary to cite the extensive literature on biological, psychological, and sociological experimentation which substantiates that the behavior of a person is shaped and influenced from the instant a sperm and ovum unite to form an individual. Variations in biological, psychological, and social influences clearly result in different patterns of behavior. That the various influences form a context in which certain behavioral patterns are reinforced and others annihilated is supported by the findings of Gallagher and Lucito: gifted, average, and retarded individuals had different subtest patterns on the Wechsler Intelligence Scale for Children. (15) The findings in a study of achievement in arithemetic by mentally retarded children conducted by Carmen J. Finley also support the focus on context in the theory. He found a significant difference in achievement related to the context in which the problem was presented. (16)

The existence and non-existence of behavior related to specific behavioral influences is not only suggested in a report by Herbert Jasper, but so is the stability of behavioral states. He reported the results of subjecting a comatose Frenchman to various auditory and tactile stimuli. Pinching the patient produced little change, but when the patient's name was called the E.E.G. record immediately changed from low arousal values to high ones. (17)

Brecher's determination of the steplike form of an auditory threshold curve for low frequencies (6) and Goesta Eckman's suggestion that "subjective magnitude" is the final outcome of a step-by-step process of transformations (18) support stationary behavioral patterns and discrete learning as called for in the theory. David Krech and Allen Calvin reported findings which show that perceptual responses proceed through a hierarchical order of levels of organization. (19) In discussing his findings on problem tendencies in children, W. C. Olson noted that the behavioral traits evaluated were distinct in nature and indicated problem tendencies. (20) Profiles of individual behavioral traits obtained through test batteries also suggest the relevance of the theory in relation to behavioral patterns.

In order to apply Schroedinger type equations, behavior must be rhythmical. That psychophysiological behavior of humans and infrahumans is rhythmical has been so well established that there is little need to cite literature. However, in The Symposia on Quantitative Biology (21) one can find many examples of periodicity in infrahuman behavior, and in Rhythmic Functions in the Living System (22) examples of periodicity in both human and infrahuman behavior. In regard to the educative context, C. V. Millard and A. J. Huggett emphasize that cyclical development is common to all aspects of growth which concern the educator, and conclude that learning influences must be phased accordingly. (23)

It was noted in the theory that the equation

$$-i\frac{B}{\Box}\dot{t} = \mathrm{L}\cap\mathrm{U} \qquad 46.$$

which was derived from the application of Schroedinger type equations to a one dimensional influence context has the same form as that derived by Lehmann for the Weber-Fechner law. According to Békésy, Lehmann's equation represents, at the present time, the best established form of the Weber-Fechner law. (24) Békésy too reports Knudsen's work on the difference limen for intensity as a function of sound pressure and tactile pressure. Figures 11 and 12 show the curves obtained for sound and tactile pressures respectively. In the figures the dotted lines represent predicted values and the solid lines the obtained ones. Referring once more to Figure 8 will show the relation between the curve predicted in the theory and Knudsen's experimentally obtained curves.

Relevance of the theory as it applies to learning is suggested by the work of J. C. Stevens and H. B. Savin (26) in which they recalculated learning

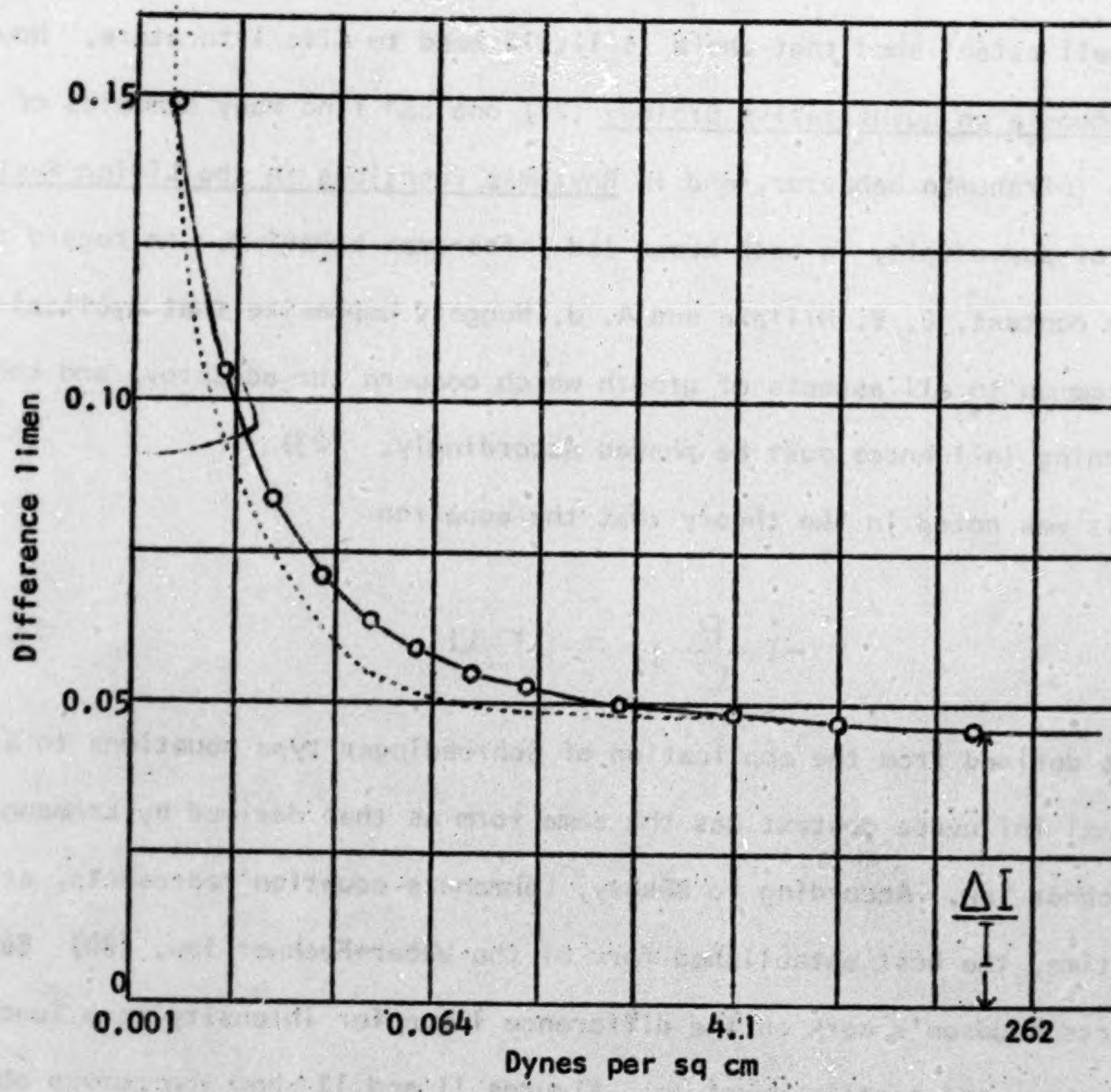


Figure 11. Knudsen's Results on the Difference Limen for Intensity as a Function of Sound Pressure (The dotted curve is calculated.)

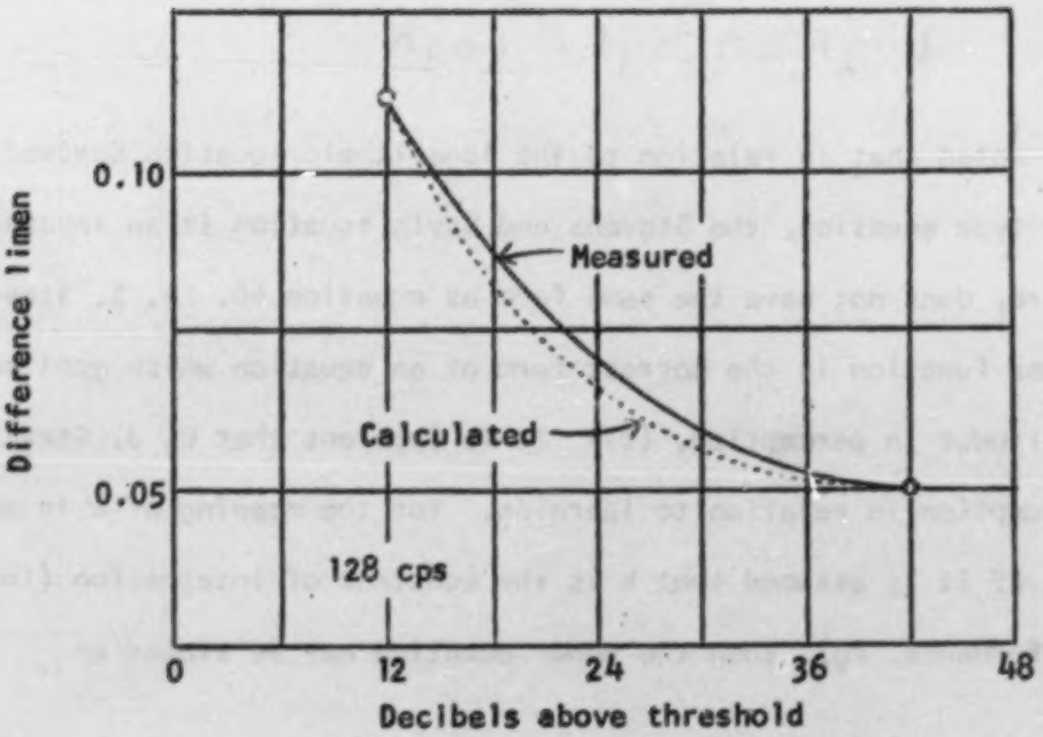


Figure 12. Difference Limens for Vibrations on the Skin

curves as power functions having the form:

$$P = Kt^{n} \qquad 47.$$

where P is the performance, k is a constant, t is the time, and n is an exponent. Expressed in logarithmic terms this equation becomes

$$\mathrm{Log}\,P = n\,\mathrm{Log}\,t + \mathrm{Log}\,K$$

It should be noted that in relation to the logarithmic equation derived from the Schroedinger type equation, the Stevens and Savin equation is an inverse function, and, therefore, does not have the same form as equation 46. S. S. Stevens insists that the power function is the correct form of an equation which explicates subjective magnitudes in perception. (27) It is apparent that C. J. Stevens makes the same assumption in relation to learning. Yet the meaning of k in equation 47 is obscure. If it is assumed that k is the constant of integration (initial value of performance, P_0), then the power equation may be stated as

$$\mathrm{Log}\,\frac{P}{P_o} = Ct$$

where C might represent the constant, $-i\frac{B}{\square}$, of equation 46, and Schroedinger type equations may be applicable to learning. Whether logarithmic or power functions represent the best form of equations for explicating and predicting learning is a question not answered by the theory, but that a quantum approach in educational theory is relevant is suggested by the work of Stevens and Savin.

Studies relevant to the BIDI effect as it relates to infrahumans have been reported. In an address at The Ohio State University in May 1963, Charles E. Osgood reported findings related to maze learning by raccoons. In this study a steaming hot bath was the stimulus which elevated the drive level of the animals, and a locked door the stimulus which induced the response. The increase in drive level resulted in intensification of previously learned behavior. J. R. Patrick and A. C. Anderson reported a similar effect in relation to maze learning by white rats. (28) Patrick's experiments with college students indicate the relevance of the BIDI effect in human learning. In this study the stimulus related to an increase in drive level was an electric shock and a locked door was the stimulus inducing the response. As with the raccoons, the students intensified their attempts to open a locked door which was unlocked during a previous trial. (29) Békésy's discussion of the error function for loudness measurements (30) indicates that error of observation is dependent upon the quantum character of behavior. If the stimulus changes in magnitude, sensory magnitude will change provided that the change is sufficient to involve one cell more or one cell less. If a given stimulus always produces the same influence then the influence can be increased by Δ or decreased by $Da - \Delta$ without a change in the number of influenced cells. Δ and $Da - \Delta$ are two values of stimulus magnitude for which the loudness is the same. Thus, in hearing--perhaps, in all behavior--there is an indeterminacy similar to that noted with respect to atomic phenomena. Figure 13 characterizes the quantum character of hearing excitation and the relationship between Δ and $Da - \Delta$.

The theory indicates that interaction of individuals within a group might demand the employment of different statistical procedures. Current discussion related to the lack of significance of differences between measures of variables

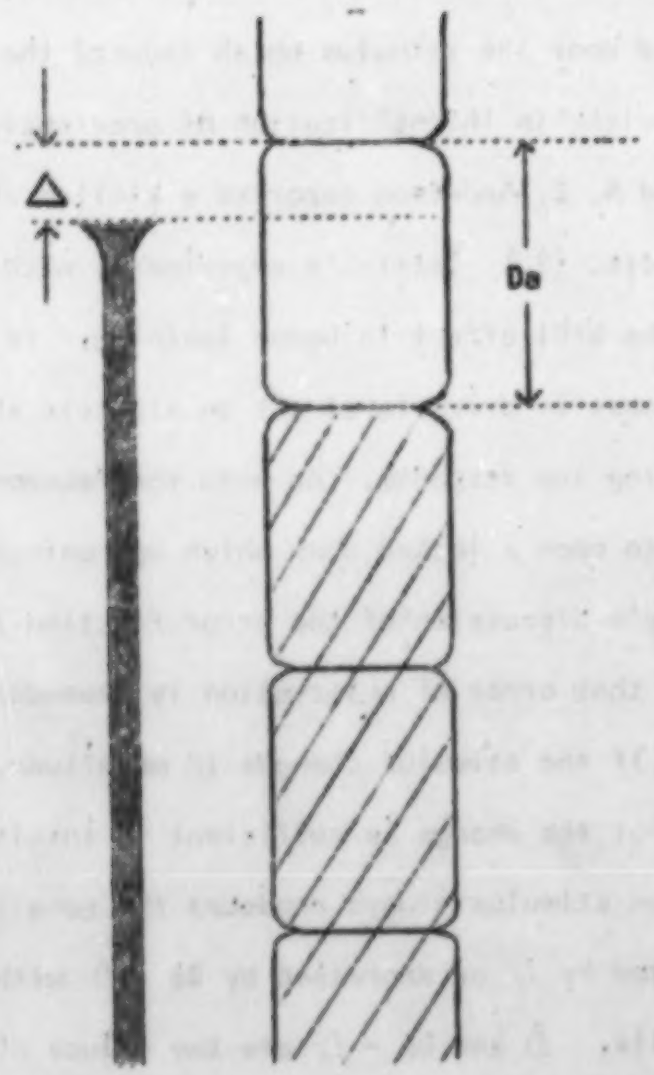


Figure 13. The Quantum Character of Excitation (31)

of interest in education seems to support the theory. Norman D. Bowers points up such difficulty inherent in the application of simple statistics in educational research. (32)

The above review of the literature indicates both the relevance and fruitfulness of the tentative projected theory to characterize behavioral phenomena including those of education. Consequently, its source, quantum theory, is significant as a devising model for educational theory.

FOOTNOTES

(1) Anyone familiar with current formalizations of quantum theory will observe that the model is eclectic and rudimentary in character. No attempt has been made to exhaust the possibilities of quantum theory as a model for educational theory. Earlier pictorial elements in the theory have been retained in an effort to make it possible for readers to visualize appropriate relationships. No refinements required by the theory of relativity have been made and development of the model is in terms of Schroedinger equations despite their limitations for solutions in quantum physics. As in physics, the equations are used to obtain first approximations.

(2) An operator is a symbolic direction to perform a mathematical procedure or a combination of procedures. For example, + is the operator for addition. In the expression,

$$\nabla^2 = \frac{\delta^2 \Psi}{\delta x^2} + \frac{\delta^2 \Psi}{\delta Y^2} + \frac{\delta^2 \Psi}{\delta z^2}$$

∇^2 is the operator notation for the second partial differentiation of Ψ with respect to the Cartesian coordinates.

(3) In a mechanical system, the sum of kinetic energy and the well-defined potential energy of that system gives the total energy of the system. The total energy of a system remains constant during the actual motion. In determining the kinetic energy of a system, at any instant, the instantaneous values of the n coordinates (q) and of n momenta (p) are used, whereas the potential energy of a system is determined by n coordinates (q) alone. The total energy of such a system with n degrees of freedom, therefore, is determined by a suitable combination of the n coordinates (q) and of the n momenta (p). The appropriate expression for total energy is called the Hamiltonian function.

(4) Normalized functions are those which contain an arbitrary factor of modulus unity. Since C_n represents a set of constants for the states of a system, C is less than one because the entire set of normalized functions must total one. That is to say

$$\int \Psi \Psi^* d\tau = 1$$

(5) Equation 12 is normalized as indicated in Footnote 4. Since

$$\Psi = \left(\phi_{(t)}\right)\left(\psi\right)$$

and ϕ is a constant at any instant of time, probabilities for ψ may be treated as the same as probabilities for Ψ.

(6) Georg von Békésy, *Experiments in Hearing*, trans. and ed. by E. G. Wever, New York: McGraw-Hill Book Company, Inc., 1960, p. 260.

(7) Arne Sollberger, "General Properties of Biological Rhythms," in *Rhythmic Functions in the Living System*, ed. by W. Wolf, Annals of the New York Academy of Science, Vol. 78, Art. 4, 1962, p. 770.

(8) von Békésy, *op. cit*., p. 247.

(9) *Ibid*, pp. 238-239.

(10) Cited in C. Murchinson, *Psychologies of 1930*, Worcester: Clark University Press, 1930, p. 213 (italics added).

(11) J. Wilder, "Modern Psychophysiology and the Law of Initial Value," in *American Journal of Psychotherapy*, Vol. 12, 1958, p. 199.

(12) James D. Block and Wagner H. Bridger, "The Law of Initial Value in Psychophysiology: A Reformation in Terms of Experimental and Theoretical Considerations," in *Rhythmic Functions in the Living System*, *op. cit*., pp. 1230-1231.

(13) S. S. Stevens, G. T. Morgan, and J. Volkmann, "Theory of the Neural Quantum in Discrimination of Loudness and Pitch," in *Americal Journal of Psychology*, Vol. 54, 1941, p. 315.

(14) P. Suppes and R. Ginsberg, "A Fundamental Property of All-or-None Models, Binomial Distribution of Responses Prior to Conditioning with Application to Concept Formation in Children," in *Psychological Review*, Vol. 70, 1963, pp. 139-161.

(15) James G. Gallagher and Leonard J. Lucito, "Intellectual Patterns of Gifted Compared with Average and Retarded," in *Exceptional Children*, Vol. 27, 1961, pp. 479-482.

(16) Carmen J. Finley, "Arithmetic Achievement in Mentally Retarded Children: The Effects of Presenting the Problem in Different Contexts," in *American Journal of Mental Deficiency*, Vol. 67, 1962, pp. 281-286.

(17) Herbert Jasper, "Reticular Cortical Systems and Theories of Integrative Action of the Brain," in Biological and Biochemical Basis of Behavior, ed. by Harry F. Harlow and Clinton N. Woolsey, Madison, Wisconsin: University of Wisconsin Press, 1958, p. 45.

(18) Goesta Ekman, "Some Aspects of Psychophysical Research," in Sensory Communication, ed. by Walter A. Rosenblith, New York: John Wiley & Sons, Inc., 1961, p. 40.

(19) David Krech and Allen Calvin, "Levels of Perceptual Organization and Cognition," in Journal of Abnormal Psychology, Vol. 48, 1953, pp. 394-400.

(20) W. C. Olsen, Problem Tendencies in Children, Minneapolis: University of Minnesota Press, 1930.

(21) The Symposia on Quantitative Biology, Vol. XXV, The Biological Laboratory, Cold Spring Harbor, L. I. N. Y., 1960.

(22) Rhythmic Functions in the Living System, ed. by William Wolf, Annals of the N. Y. Academy of Sciences, Vol. 78, Art. 4, Oct. 30, 1962.

(23) C. V. Millard and A. J. Huggett, Growth and Learning in the Elementary School, Boston: D. C. Heath Co., 1946.

(24) von Békésy, op. cit., p. 247.

(25) Ibid., pp. 248-249.

(26) J. C. Stevens and H. B. Savin, "On the Form of Learning Curves," in Journal of the Experimental Analysis of Behavior, Vol. 5, 1962, pp. 15-18.

(27) S. S. Stevens, "The Psychophysics of Sensory Function," in Sensory Communication, op. cit., p. 2.

(28) J. R. Patrick and A. C. Anderson, "The Effect of Incidental Stimuli on Maze Learning with the White Rat," in Journal of Comparative Psychology, Vol. 10, 1930, pp. 295-307.

(29) J. R. Patrick, "Studies in Rational Behavior and Emotional Excitement, II. The Effect of Emotional Excitement on Rational Behavior in Human Subjects," in Journal of Comparative Psychology, Vol. 18, 1934, pp. 153-195.

(30) von Békésy, op. cit., pp. 239-245.

(31) Ibid., p. 240.

(32) Norman D. Bowers, "Learning: Task and Method Variables," in Review of Educational Research, Vol. 31, 1961, p. 535.

AN EDUCATIONAL THEORY MODEL:
THEORY OF LOCAL AND COSMOPOLITAN INFLUENTIALS*

by Robert E. Jewett

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Educational Theory Model

A model taken from a theory of influentials--local and cosmopolitan (1) --will be presented. The terms 'local' and 'cosmopolitan' as used in this model do not apply to the geographical area in which the interpersonal influence is exercised. Indeed both types of influentials are effective primarily within the local community; and this model is confined exclusively to the local community.

The criterion for distinguishing between the two types of influentials is centered in their orientation to the local community. The local influential is preoccupied with local problems and interests to the virtual exclusion of the national and international scene. The cosmopolitan influential, while he has a minimum of interest in local affairs, is concerned chiefly with the world outside the local community and he regards himself as an integral part of that world.

To state the distinction between the two categories of influentials in different terminology, the local influential is parochial while the cosmopolitan influential is ecumenical. The former finds his reference group within the local community; the latter within the national or international community.

Now that the basic distinction has been made between the two types of influentials, we shall set forth the correlative behavior that stems from the two personality types.

Structure of Social Relationships

(1) The local influential possesses an intense loyalty to the local community.

(2) The cosmopolitan influential possesses an intense loyalty to his business or professional group or the national or international scene rather than to the local community.

(3) The local influential expresses a strong preference to remain in the local community. He does not believe that he would be as happy or successful in another community.

(4) The cosmopolitan influential expresses a willingness to live elsewhere. He believes that he would be at least as happy or successful in another community.

(5) The local influential, to the extent that he is influenced by persons or groups outside the local community, is influenced by those in the immediate geographical region.

(6) The cosmopolitan influential, to the extent that he is influenced by persons or groups within the local community, is influenced by those within the business or profession to which he belongs.

(7) The local influential tends to be tradition oriented, especially to the dominant local tradition.

(8) The cosmopolitan influential tends to be future oriented, especially to the dominant aspirations of his business or professional group at the national or international level.

(9) The local influential, in a large majority of cases, has spent most of his life in the local community.

(10) The cosmopolitan influential, in a large majority of cases, is a relative newcomer to the local community.

(11) The age of the influential or the amount of time that he has spent in his vocation does not determine the category to which he belongs.

(12) The local influential is interested in establishing frequent contacts with many people in the local community. He wishes to know people representing a wide variety of vocational and cultural interests.

(13) The cosmopolitan influential is not interested in the frequency or the quantity of his contacts. Rather he is selective in making contacts with people. He prefers to know those people who share his vocational and cultural interests.

(14) The difference in personal contact preference between the two types of influentials exists irrespective of the occupation of the influential.

(15) The local influential joins those organizations which are designed for making contacts.

(16) The cosmopolitan influential joins those organizations in which he can exercise his special skills and knowledge.

(17) The local influential tends to hold those public offices that are political in nature--offices that are usually obtained through political and personal contacts.

(18) The cosmopolitan influential tends to hold those public offices that require the exercise of his special skills and knowledge.

(19) The local influential is less critical of working conditions and economic opportunity within the local community than is his cosmopolitan counterpart.

(20) The local influential, who works within a bureaucracy, is committed to the bureaucratic structure and he seeks recognition within that structure.

(21) The cosmopolitan influential, who works within a bureaucracy, is committed to professional groups beyond the local community, and therefore, he does not seek recognition within the bureaucratic structure.

(22) The local influential believes in adhering closely to rules when operating within an institutional framework.

(23) The cosmopolitan influential does not view rules as ends and he will ignore rules when they stand in the way of achieving his goals.

(24) The local influential resents adverse criticism of the local community by professional and political groups organized on the national scale.

(25) The cosmopolitan influential tends to accept adverse criticism of the local community by professional and political groups organized on the national scale.

(26) There is a greater possibility that a cosmopolitan influential will become a local influential with the passage of time than that a local influential will become a cosmopolitan.

Avenues of Interpersonal Influence

(1) The effectiveness of the local influential within the local community rests on an elaborate network of personal relationships.

(2) The effectiveness of the cosmopolitan influential within the local community rests on his special skills and knowledge.

(3) The local influential's rise to prominence is slower than is the rise of the cosmopolitan influential.

(4) The local influential who has grown up in the local community must disengage himself from obsolete images of himself as "a boy" before he becomes accepted as an influential.

(5) The cosmopolitan influential, who has not grown up in the local community, comes into the local community with prestige established elsewhere.

(6) The cosmopolitan influential is more vulnerable to local criticism than is the local influential.

Social Status in Action: Interpersonal Influence

(1) Persons in the local community seek out the local influential because of his sympathetic understanding.

(2) Persons in the local community seek out the cosmopolitan influential because of his specialized knowledge and skills.

(3) Interpersonal influence exerted by the cosmopolitan influential on a member of the local community usually involves some social distance between the two persons.

(4) Interpersonal influence exerted by the local influential on a member of the local community usually involves close personal relations between the two persons.

(5) The local influential is more interested in giving advice to local community members than is the cosmopolitan influential.

(6) The local influential is more interested in giving personal advice than he is in advising on matters of business or professional import.

(7) The cosmopolitan influential is more interested in giving advice of a technical or professional nature than he is in advising on matters of a personal nature.

(8) The cosmopolitan influential reads more than does the local influential.

(9) The cosmopolitan influential, in contrast to the local influential, reads material which deals with national and international affairs.

(10) The cosmopolitan influential reads metropolitan newspapers, while the local influential reads local newspapers.

(11) The cosmopolitan influential has a preference for radio and television news analysts, while the local influential shows a preference for newscasters. The latter type of influential also prefers newscasters who "personalize" the news.

(12) The cosmopolitan influential tends to be monomorphic in that he exerts influence in one rather narrowly defined area, e.g. the area of politics.

(13) The local influential tends to be polymorphic in that he exerts influence in a variety of spheres.

(14) The local influential tends to be a conservative within the local community in that he accepts the dominant values of the community and works for their preservation.

(15) The cosmopolitan influential tends to be a liberal within the local community in that he accepts the dominant values of the wider culture which are often at variance with the local community's values. He attempts to foster these "outside" values in the local community.

(16) In a local community which is in process of economic and social deterioration, the cosmopolitan influential will leave the community at an early stage of the process. The local influential will delay his departure from such a community until the process is in an advanced stage, or he may elect to remain permanently in the local community.

(17) The cosmopolitan influential who operates in a local community which is permeated with a metropolitan atmosphere is more effective than is the cosmopolitan influential of equal ability who operates within a community whose atmosphere is parochial.

(18) The local influential who operates in a local community which is permeated with a parochial atmosphere is more effective than is the local influential of equal ability who operates within a community whose atmosphere is cosmopolitan.

(19) The local influential rather than the cosmopolitan influential tends to dominate the local community which is culturally and economically deprived.

(20) The cosmopolitan influential rather than the local influential tends to dominate the local community which is culturally and economically advanced.

(21) A cosmopolitan influential is less secure in the face of criticism emanating from the local community than is the local influential under similar circumstances.

Educational Theory

Designation of Equivalent Terms

In describing features of the local community, terms have been used for which equivalent terms will be employed in describing corresponding features of the local university or college. Therefore, the reader is provided a comparison of such terms below.

(1) The local influential is the equivalent of the institution oriented professor.

(2) The cosmopolitan influential is the equivalent of the discipline oriented professor.

(3) Business and professional groups on the national and international scene are the equivalent of academic groups on the national and international scene.

Professor Orientations

The institution oriented professor largely confines his professional interests to the local university or college. He is preoccupied with interests and problems centered in the local educational institution to the virtual exclusion of academic groups of the national or international scene. The institution oriented professor is parochial. He finds his reference group within the local university or college.

The discipline oriented professor, while he has a minimum of interest in the local university or college, is primarily concerned with his academic discipline on the national and international scene. The discipline oriented professor is ecumenical. He finds his reference group within his discipline on the national and international scene.

Structure of Social Relationships

(1) The institution oriented professor possesses an intense loyalty to the local university or college.

(2) The discipline oriented professor possesses an intense loyalty to his academic discipline rather than to the local university or college.

(3) The institution oriented professor expresses a strong preference to remain at the local university or college rather than move to another institution. He does not believe that he would be as happy or successful at another university or college.

(4) The discipline oriented professor expresses a willingness to leave the local university or college if by so doing he can enhance his opportunities to succeed in his academic discipline. He believes that such a move has possibilities for him.

(5) The institution oriented professor, to the extent that he is influenced by persons or groups outside the local university or college, is influenced by those in the community in which the university or college is located.

(6) The discipline oriented professor, to the extent that he is influenced by persons or groups within the local university or college, is influenced by those within his own department.

(7) The institution oriented professor tends to be tradition oriented, especially to the dominant tradition of the local university or college.

(8) The discipline oriented professor tends to be future oriented, especially to the dominant aspirations of his academic group at the national or international level.

(9) The institution oriented professor, in a large majority of cases, has spent most of his academic career in the local university or college.

(10) The discipline oriented professor, in a large majority of cases, is a relative newcomer to the local university or college.

(11) The age of the professor or the amount of time that he has spent in his profession does not determine the category to which he belongs.

(12) The institution oriented professor is interested in establishing frequent contacts with many staff members in the local university or college. He wishes to know people representing a wide variety of professional interests.

(13) The discipline oriented professor is not interested in the frequency or the quantity of his contacts, rather he is selective in making contacts with staff members. He prefers to know those fellow professors who share his academic interests.

(14) The difference in personal contact preference between the two types of professors exists irrespective of the area of specialization of the professor.

(15) The institution oriented professor prefers to be a member of those faculty committees whose concerns are administrative problems of the university or college and whose personnel cut across department lines.

(16) The discipline oriented professor prefers to be a member of those faculty committees whose concerns are academic problems within his discipline and whose personnel is confined to his own department.

(17) The institution oriented professor is less critical of heavy teaching loads and low salaries within the local university or college than is his discipline oriented counterpart.

(18) The institution oriented professor primarily seeks recognition within the matrix of the local university or college rather than within the national organization of his academic discipline.

(19) The discipline oriented professor primarily seeks recognition within the national organization of his academic discipline rather than within the matrix of the local university or college.

(20) The institution oriented professor believes in adhering closely to rules when operating within the framework of the local university or college.

(21) The discipline oriented professor does not view rules as ends and he will ignore rules when they stand in the way of his academic goals.

(22) The institution oriented professor resents adverse criticism of the local university or college by academic groups organized on the national scale, i.e. A.A.U.P.

(23) The discipline oriented professor tends to accept adverse criticism of the local university or college by academic groups organized on the national scale.

(24) There is a greater possibility that a discipline oriented professor will become an institution oriented professor with the passage of time than that the reverse process will occur.

Avenues of Interpersonal Influence

(1) The effectiveness of the institution oriented professor within the local university or college rests on an elaborate network of personal relations.

(2) The effectiveness of the discipline oriented professor within the local university or college rests on his special skills and knowledge.

(3) The institution oriented professor's rise to prominence in the local university or college is slower than is the rise of the discipline oriented professor.

(4) The institution oriented professor, who has received his graduate training at the local university or college, must disengage himself from obsolete images of himself as "a graduate student" before he becomes accepted as a "real" professor.

(5) The institution oriented professor, who has not received his graduate training at the local university or college, comes into the local university or college with prestige established elsewhere.

(6) The discipline oriented professor is more vulnerable to criticism within the local university or college than is the institution oriented professor.

Social Status in Action: Interpersonal Influence

(1) Persons within the local university or college seek out the institution oriented professor because of his sympathic understanding.

(2) Persons in the local university or college seek out the discipline oriented professor because of his specialized knowledge and skills.

(3) Interpersonal influence exerted by the discipline oriented professor on a member of the local faculty usually involves some social distance between the two persons.

(4) Interpersonal influence exerted by the institution oriented professor on a member of the local faculty usually involves close personal relationship between the two persons.

(5) The institution oriented professor is more interested in giving advice to local faculty members and students than is the discipline oriented professor.

(6) The institution oriented professor is more interested in giving personal advice than he is in advising on matters of academic import.

(7) The discipline oriented professor is more interested in giving advice on academic matters than he is in advising on matters of a personal nature.

(8) The discipline oriented professor is more interested in conducting research and writing than is the institution oriented professor. The former is more productive in the areas of research and writing than is the latter.

(9) The institution oriented professor is more interested in teaching than he is in research and writing.

(10) The discipline oriented professor tends to be monomorphic in that he exerts influence in one rather narrowly defined area--the area of his academic competency.

(11) The institution oriented professor tends to be polymorphic in that he exerts influence in a variety of spheres--in areas of personal living as well as in his area of academic competency.

(12) The institution oriented professor tends to be a conservative within the local university or college in that he accepts the dominant values of the college and works for their preservation.

(13) The discipline oriented professor tends to be a liberal within the local university or college in that he accepts the dominant values of his academic discipline as expressed at the national or international level, which are often at variance with the local university's or college's values. He attempts to foster these "outside" values in the local university or college.

(14) In a university or college which is in the process of intellectual and academic deterioration, the discipline oriented professor will leave the university or college at an early stage of the process. The institution oriented professor will delay his departure from such a university or college until the process is in an advanced stage, or he may elect to remain.

(15) The discipline oriented professor who works in a university or college which is permeated with a cosmopolitan atmosphere is more productive (research and writing) than is the discipline oriented professor of equal ability who works in a university or college whose dominant ethos is parochial.

(16) The institution oriented professor who works in a university or college whose atmosphere is permeated with a parochial atmosphere is a more effective classroom teacher than is the institution oriented professor who works in a university or college whose dominant ethos is cosmopolitan.

(17) The institution oriented professor rather than the discipline oriented professor tends to dominate the university or college which is "second rate."

(18) The discipline oriented professor rather than the institution oriented professor tends to dominate the university or college which is "first rate."

(19) The discipline oriented professor is less secure in the face of criticism emanating from the local university or college than is the institution oriented professor under similar circumstances.

Significance of Model

Paul F. Lazarsfeld and Wagner Thielens, Jr. in their book The Academic Mind specifically discuss the roles of local and cosmopolitan influentials. (2) The professor who is loyal to the college tends to be a conservative; while the professor whose loyalty is focused on his academic discipline tends to be permissive. (3) The conservative is defined as one who "believes that certain types of opinions - i.e. Communism - should be stamped out as a matter of principle." (4) The permissive professor is willing to explore unorthodox ideas and he accepts colleagues who have a similar commitment. The authors hold that, "Permissive teachers /i.e. discipline oriented professors/ are more likely to achieve professional distinction" (5). Yet, professors in this category, the authors contend, are more apprehensive than the conservative professors /i.e. institution oriented professors/ in the face of community pressures for conformity.

David Gottlieb in an article entitled, "American Graduate Students: Some Characteristics of Aspiring Teachers and Researchers" deals specifically with localism and cosmopolitanism. (6) Graduate students were placed in the above categories on the basis of their responses to the following question: "In the long run would you rather be known and respected (a) throughout the institutions where you work, or (b) among specialists in your field in different institutions?" (7) Those graduate students who were research oriented fell into the cosmopolitan classification, while the ones who were teaching oriented fell into the local grouping.

E. Quarantelli in an article in the Journal of Educational Sociology reports findings relevant to the educational theory developed in this paper. (8) From a study conducted in a dental school, Professor Quarantelli concludes that the more strongly committed one is to a specific profession, the more sensitive one is to lay criticism of that profession. Also, according to the study, the strongly discipline committed tend to qualify, discriminate, and rationalize lay criticism.

Leonard Reissman in Social Forces presents an analysis of types of bureaucrats which incorporates the concepts of local and cosmopolitan, but in different terminology. (9)

The research study which is most germaine to the educational theory set forth in this paper is that of Alvin W. Gouldner reported in the Administrative Science Quarterly. (10) Gouldner, referring to a university or college context, defines the cosmopolitan as one who (a) expresses a low degree of loyalty to the college, (b) expresses a deep commitment to the area of his specialized role skills, and (c) is outer reference group oriented. The local has the opposite pattern of loyalties. He divides the local category into four sub-categories: (a) the dedicated, (b) the true bureaucrat, (c) the home guard, and (d) the elder. Furthermore, he reports the following major findings (11):

(1) Cosmopolitans to a greater degree than locals desire lighter teaching loads in order to have time for research and writing.

(2) Cosmopolitans found few persons within the college with whom to share professional interests.

(3) Cosmopolitans published more than did the locals.

(4) Cosmopolitans would more readily leave the college than would the locals.

(5) Cosmopolitans in comparison with the locals knew fewer faculty members.

(6) Cosmopolitans are less opposed to A.A.U.P. intervention in the college than are the locals.

(7) Cosmopolitans receive more intellectual stimulation from sources outside the college than from inside sources.

(8) Cosmopolitans, to a greater extent than locals, consider professorial salaries to be low.

In Constraint and Variety in American Education, David Riesman makes use of the concepts of local and cosmopolitan. (12) Riesman points up areas of conflict between the locals and the cosmopolitans. He delineates the relationship between the "home guard" and the local community, and the significance of this relationship for local-cosmopolitan interaction.

Robert K. Knapp's chapter in The American College contains material which is relevant to the educational theory under consideration. (13) Knapp refers to the conflict between institutional loyalty and loyalty to the discipline. He speaks of the conflict between the teaching and the research functions. The chapter contains an excellent historical analysis of the development of trends leading to the above stresses.

An article by D. J. McCarty in the American School Board Journal suggests the possibility of extending our analysis to the elementary and secondary school. (14) The two groups of teachers are described, although they are not identified.

Dorothy Soeberg and Lois Williams, writing in the California Journal of Elementary Education, attempt to identify significant characteristics of successful teachers. (15) The article suggests that prospective teachers are expected to take on the values of the discipline oriented when in college and then as a teacher the person is required to be institution oriented.

This brief review of the literature has indicated the relevance of the educational theory, and so the significance of the model from which it was derived.

FOOTNOTES

(1) The terms 'local' and 'cosmopolitan' are used here in the sense that Robert K. Merton defined and applied them in *Social Theory and Social Structure*, Glencoe, Ill.: The Free Press, Revised and enlarged edition, 1957, pp. 393-420. The model is patterned from Merton's treatment cited above. The model includes extensions and interpretations of Merton's material for which the present writer only can be held accountable.

The terms have been used widely in sociological literature; however, often with a somewhat different meaning and application than is found in Merton's writings. See for example, Carle C. Zimmerman, *The Changing Community*, New York: Harper and Brothers, 1938, pp. 80-84; Leopold von Wiese and Howard Becker, *Systematic Sociology*, New York: John Wiley and Sons, 1932, pp. 223-226; and Ferdinand Toennies, *Fundamental Concepts of Sociology*, New York: American Book Company, 1940.

(2) Paul F. Lazarsfeld and Wagner Thielens, Jr., *The Academic Mind*, Glencoe, Illinois: The Free Press, 1958, p. 263.

(3) *Ibid*., Chapter VI.

(4) *Ibid*., p. 120.

(5) *Ibid*., p. 144.

(6) David Gottlieb, "American Graduate Students: Some Characteristics of Aspiring Teachers and Researchers," in *Journal of Educational Psychology*, Vol. 52, 1961, pp. 236-240.

(7) *Ibid*., p. 237.

(8) E. Quarantelli, "School Learned Adjustment to Negative Self Images in High Status Occupational Roles: The Dental School Example," in *Journal of Educational Sociology*, Vol. 35, 1961, pp. 165-171.

(9) Leonard Reissman, "A Study of Role Concepts in Bureaucracy," in *Social Forces*, Vol. 27, 1949, pp. 305-310.

(10) Alvin W. Gouldner, "Cosmopolitans and Locals: Toward an Analysis of Latent Social Roles," I and II in *Administrative Science Quarterly*, Vol. 2, 1957-1958, pp. 281-306, 444-480.

(11) *Ibid*., pp. 295-296.

(12) David Riesman, Constraint and Variety in American Education, New York: Doubleday and Company, Inc., 1958.

(13) Nevitt Sanford, The American College, New York: John Wiley and Sons, Inc., 1962, Chapter VII.

(14) D. J. McCarty, "Organizational Influences on Teacher Behavior," in American School Board Journal, Vol. 143, 1961, pp. 13-14.

(15) Dorothy Soeberg and Lois Williams, "A Portrait of Successful Teachers," in California Journal of Elementary Education, Vol. 29, 1961.

AN EDUCATIONAL THEORY MODEL: INFORMATION THEORY*

by Elizabeth Steiner Maccia

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"And now, which of these finger-posts ought I to follow, I wonder?"

It was not a very difficult question to answer, as there was only one road through the wood, and the two finger-posts both pointed along it. "I'll settle it," Alice said to herself, "when the road divides and they point different ways."

I. INTRODUCTION

Information theory is a formal theory, a branch of probability theory. Nevertheless its development has been in a semantic context, in the context of communication theory. It was initiated by those studying electrical communication equipment. The principal originator was Claude Shannon who, in the now famous paper of 1948 appearing in the Bell System Technical Journal, stated:

> We have represented a discrete information source [e.g. telegraphy where the message is a sequence of letters and the signal a sequence of dots, dashes, and spaces] as a Markoff process. Can we define a quantity which will measure, in some sense, how much information is "produced" by such a process, or better, at what rate information is produced?
>
> Suppose we have a set of possible events whose probabilities of occurrence are $p_1, p_2, \ldots, p_n$. These probabilities are known but that is all we know concerning which event will occur. Can we find a measure [$H(p_1, p_2, \ldots, p_n)$] of how much "choice" is involved in the selection of the event or of how uncertain we are of the outcome? (1)

Shannon's answer to this question was affirmative and took the form of a basic information function:

> . . . the following result is established . . .
>
> $$H = -K \sum_{i=1}^{n} p_i \log p_i$$
>
> where K is a positive constant. (2)

So emerged the basic cornerstone to the study of communication.

Since it is obvious that communication is central in the educative process, communication theory surely has bearing upon educational theory. Indeed one can find statements in the literature such as

> . . . teachers who are concerned about teaching well cannot afford to neglect communication theory. (3)

Furthermore, since information theory has seen its development within the context of communication theory, the suggestion that information theory might be a model for devising educational theory presents itself. This suggestion is substantiated by the extensive utilization of information theory within psychology. (4) The suggestion has presented itself to others concerned with educational theory. Consider writings, similar to the Packers' (5), in which information theory is brought into conjunction with educational theory. There has been, however, no working out, to any great extent, of this conjunction. It is the purpose of this paper to do just that.

II. THE EDUCATIONAL THEORY MODEL

Information Functions

To begin setting forth information theory as an educational theory model, 'information' must be given precise meaning. This precise meaning has a connection with our everyday meaning. We need information only when we do not know something. We must be uncertain or faced with a choice between alternatives. Complete knowledge involves no uncertainty. There are no alternatives, because there is only one way. No information is involved or transmitted. Where there is only one road, there is no need for finger-posts. There is nothing to settle. To point direction for Alice, who is not in a state of quandry because there is only one way for her to go, does not convey information. Complete ignorance, too, does not involve uncertainty. There are no alternatives, because one is not aware that there are ways. Alice wisely admits that her state of ignorance as to what is ahead precludes settlement until she becomes aware of the alternatives. There must be a specifiable set of alternatives, if there is to be uncertainty.

There are degrees of uncertainty. If many choices are open to us, we are more uncertain as to how to proceed. We require more information. More information is involved in the case of more alternatives. Moreover, within the range of choices, the choice that is less probable entails more uncertainty than the choice that is more probable. More information is involved in the less probable than the more probable. Information, then, is associated with uncertainty, and uncertainty is associated with a selection process involving probability considerations.

To state the matter in a more formal way (6), information functions are defined with respect to ensembles. Ensembles are determined by elements, classifications, and probability measures. The classifications are the sets of names for states (classes). They are the variables of the ensemble, and are designated by lower case letters, 'x, y, z, u, v, w.' Each element of the ensemble must be in one and only one state of each classification, since a particular state of a classification is one of the alternatives. A particular state specifies a variable for an element. Particular states in any one classification are designated by numerical subscripts, e.g. 'x_1, y_3, z_2, etc.' A subscript 'i, j, k, etc.' indicates any one particular state in the classification. If there is uncertainty, it is about the particular state of elements in one or more classifications. Probability measures relate to one or more classifications:

'$p(x_i)$' denotes the probability of a given element being in state x_i of classification x;

'$p(x_i,y_j)$' denotes the probability of a given element being both in state x_i of classification x and state y_j of classification y; and

'$p_{x_i}(y_j)$' denotes the probability of a given element being in state y_j of y, given it is in state x_i of x.

H-Function

Illustrations will be presented to lead into the definition of the basic information function designated by 'H.' Assume that a friend is in one of two classrooms, and assume also that it is equally likely that he is in either one of them. That is to say, there are two possible states within a classification for the element, and both are equally likely. There are two equiprobable alternatives. The probability of the element being in one or the other state would be one-half, since $p = \frac{1}{n}$ where n denotes the number of equiprobable alternatives. Assume further that you are uncertain, you do not know in which classroom he is. There is information that can be transmitted. If there was only one classroom your friend could be in, then there would be no uncertainty and no information that could be transmitted. It takes a minimum of two classrooms for uncertainty and information. If there were more classrooms than two that he could be in, the uncertainty would increase and so would the information. Therefore, $H = n$. (Also $H = \frac{1}{p}$, since $n = \frac{1}{p}$.) However, a logarithmic relation where the log is taken to base 2 is postulated on the grounds of what has been called Shannon's Fundamental Coding Theorem: messages of an ensemble having an average information value, H, can be encoded into not less than H binary, equally likely symbols. Therefore, $H = \log_2 \frac{1}{p}$. In terms of the illustration, the decision as to the location of the friend is binary. It has a twofold quality, inclusion of one alternative and exclusion of the other. He is in one classroom and not in the other. This one decision is all it takes to find out. The information contained can be encoded into one binary, equally likely symbol. There is one unit of information or one bit where 'bit' is the abbreviated form of 'binary digit.' In binary numbers (a number system which is twofold, 0 and 1), a single digit specifies a choice from two alternatives. One bit involves one binary digit. See Figure 1. The number of bits increases as the uncertainty increases. Assume that another friend is in one of eight classrooms. The number of bits involved would be 3. ($H = \log_2 8 = 3$.) See Figure 2. Notice that in a choice situation, the number of bits gives us the number of appropriate binary decisions. An appropriate binary decision excludes exactly one-half of the alternatives from consideration. In other words, a set of alternatives can be mapped into sequences of one-bit choices.

The H-function can be generalized to include alternatives that are not equally likely. Each choice may have a different informational value. By summing over the amount of information associated with each choice or selection, weighted by the probability that the selection will occur, the value of H can be obtained. To state the matter more precisely, $H(x)$ is the average uncertainty per element with reference to the classification x; it is the average number of decisions needed to associate any one element in the ensemble with some state x_i in x, with the provision that the decisions are appropriate; it is a function of the probability measures in x:

$$H(x) = \sum_{i=1}^{r} p(i) \log_2 \frac{1}{p(i)}$$

One recognizes Shannon's measure as stated on page 298 of this report.

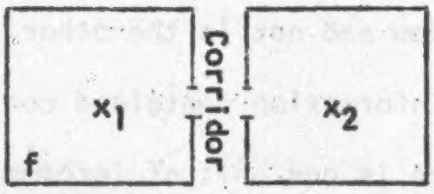


FIGURE 1: Schema of Site of Friend in One of Two Classrooms
'x_1,x_2' denote the possible states (in one of two classrooms) of the element (friend) denoted by 'f.'
One form of appropriate binary decision: Is f in x_1? Yes
Binary representation where '1' denotes Yes: 1

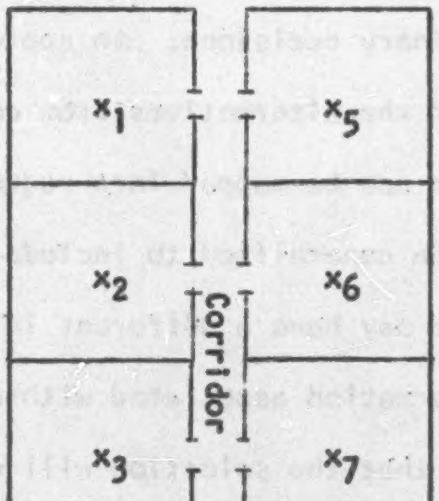


FIGURE 2: Schema of Site of Friend in One of Eight Classrooms
'x_1,...,x_8' denote the possible states (in one of eight classrooms) of the element (friend) denoted by 'f.'

One form of appropriate binary decisions:	**Is f in x_1 through x_4?**	**No.**
	Is f in x_5 or x_6?	**No.**
	Is f in x_7?	**No.**

Binary representation where '0' denotes No: 000

Finally, the H-function can be stated so that elements classified in two or more ways can be taken into account; i.e. joint probabilities and conditional probabilities can be taken into account. The measure for joint uncertainties, $H(x,y)$, would be

$$\sum_i \sum_j p(i,j) \log_2 \frac{1}{p(i,j)}$$

The measure for conditional uncertainties, $H_x(y)$, would be

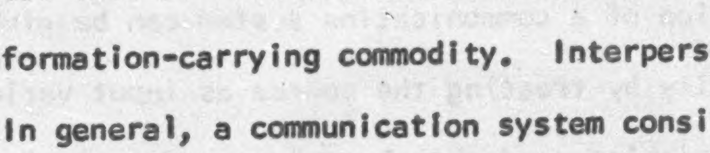
$$\sum_i \sum_j p(i,j) \log_2 \frac{1}{p_i(j)}$$

The three H-measures are related as follows:

$$H(x) + H_x(y) = H(x,y)$$

H-Function and Communication

The process called 'communication' is seen as a flow of some information-carrying commodity in some network. The commodity and network need not be constructed ones as in electrical communication. Ordinary language, too, is an information-carrying commodity. Interpersonal relationships, too, are networks. In general, a communication system consists of three parts: a source, a destination, and a channel which establishes the connection between the two and so the possibility of transmitting information. A communication system may be schematized as follows:



The illustrations which led into a definition of the H-function also may be utilized to place that function in the context of communication. The communication system would be constituted by the source: the situation which is to be observed--the friend in one or the other classrooms; the destination: the observer--the person who is uncertain as to the classroom in which his friend is; and the channel: the atmosphere through which the light rays pass from what is to be observed to the observer and the eye and nervous system of the observer through which the sensation passes. In this communication system, H was taken to be the same for the source and the destination. That is to say, the measure of information or uncertainty could be taken with the same results from the standpoint of what was to be observed or from that of the observer. The channel did not make a difference. The received message was simply a function of the source message or vice versa. Stated differently, there was no source of information other than the source of the communication system or there was no noise, and there was no loss of information or there was no error.

The conception of a communication system can be given more precision and greater generality by treating the source as input variables, the destination as output variables, and the channel as a description of association between variables through designation of the conditional probability of each output for each input. The channel, then, becomes expressible as a matrix of the form, $\left\{P(y_j|x_i)\right\}$, and so channel is widened beyond its ordinary meaning as a medium of conveyance.

Figure 3 depicts four possible channels. In Case I, we have the case of our illustrations. There is as much information in the output as the input,

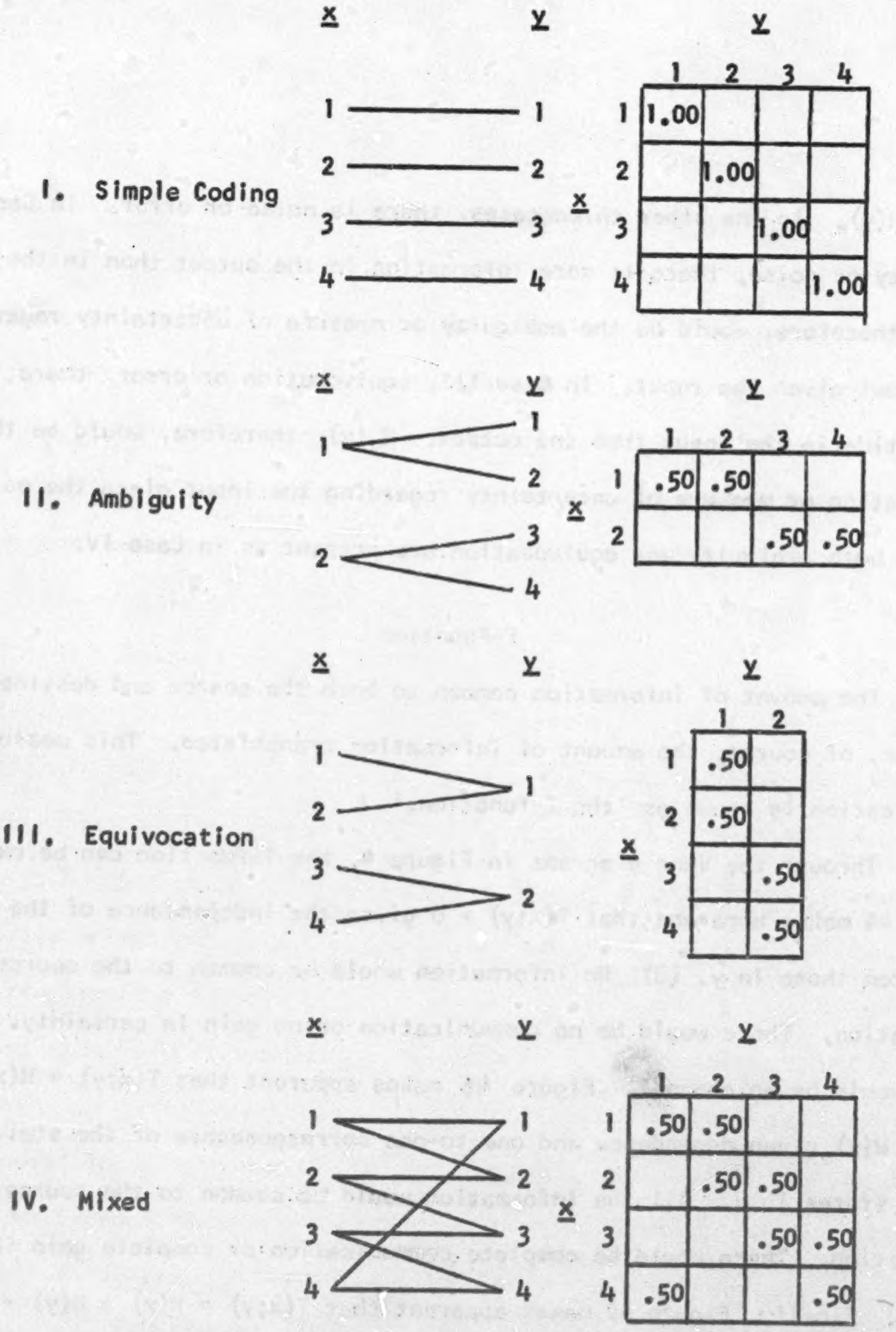

I. Simple Coding
x
y
1 — 1
2 — 2
3 — 3
4 — 4
y: 1 2 3 4
x 1: 1.00
x 2: 1.00
x 3: 1.00
x 4: 1.00
II. Ambiguity
x
y
1 — 1, 2
2 — 3, 4
y: 1 2 3 4
x 1: .50 .50
x 2: .50 .50
III. Equivocation
x
y
1, 2 — 1
3, 4 — 2
y: 1 2
x 1: .50
x 2: .50
x 3: .50
x 4: .50
IV. Mixed
x
y
y: 1 2 3 4
x 1: .50 .50
x 2: .50 .50
x 3: .50 .50
x 4: .50 .50

FIGURE 3: Schema of the possible correspondences between inputs (x) and outputs (y). The right hand figure in each case is the probability matrix; cell entries are the probability of y given x = $p_x(y)$. The conditional probabilities for Cases II, III, and IV are arbitrary. (7)

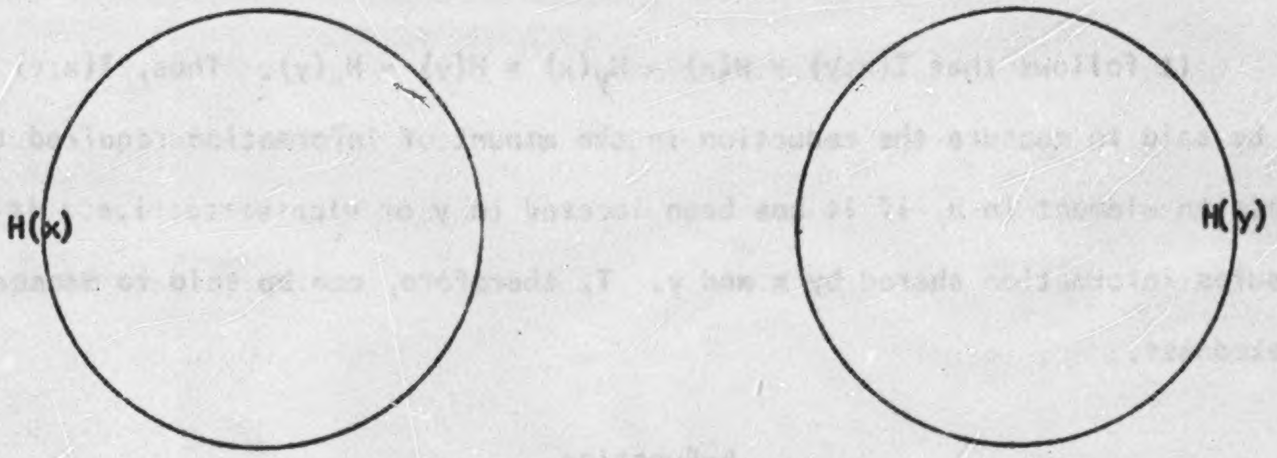
$H(x) = H(y)$. In the other three cases, there is noise or error. In Case II, ambiguity or noise, there is more information in the output than in the input. $H_x(y)$, therefore, would be the ambiguity or measure of uncertainty regarding the output given the input. In Case III, equivocation or error, there is more information in the input than the output. $H_y(x)$, therefore, would be the equivocation or measure of uncertainty regarding the input given the output. Usually both ambiguity and equivocation are present as in Case IV.

T-Function

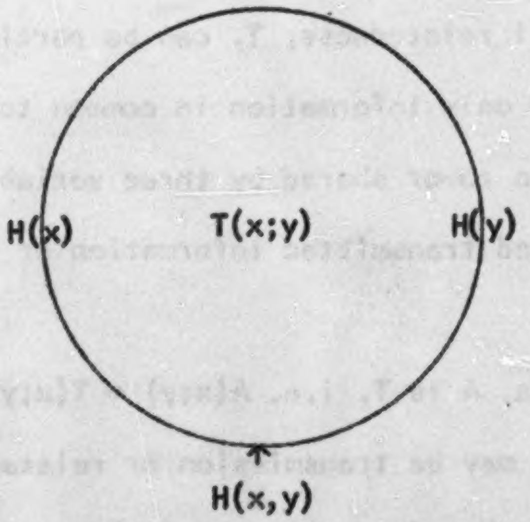
The amount of information common to both the source and destination would be, of course, the amount of information transmitted. This measure of communication is known as 'the T-function.'

Through the Venn diagrams in Figure 4, the T-function can be explicated. Figure 4A makes apparent that $T(x;y) = 0$ given the independence of the states in x from those in y. (8) No information would be common to the source and the destination. There would be no communication or no gain in certainty. In fact, there would be no channel. Figure 4B makes apparent that $T(x;y) = H(x,y) = H(x) = H(y)$ given dependence and one-to-one correspondence of the states in x to the states in y. All the information would be common to the source and the destination. There would be complete communication or complete gain in certainty. Finally, Figure 4C makes apparent that $T(x;y) = H(x) + H(y) - H(x,y)$ given dependence but not one-to-one correspondence of the states in x to y. All the information would not be common to the source and the destination. There would be incomplete communication or incomplete gain in certainty.

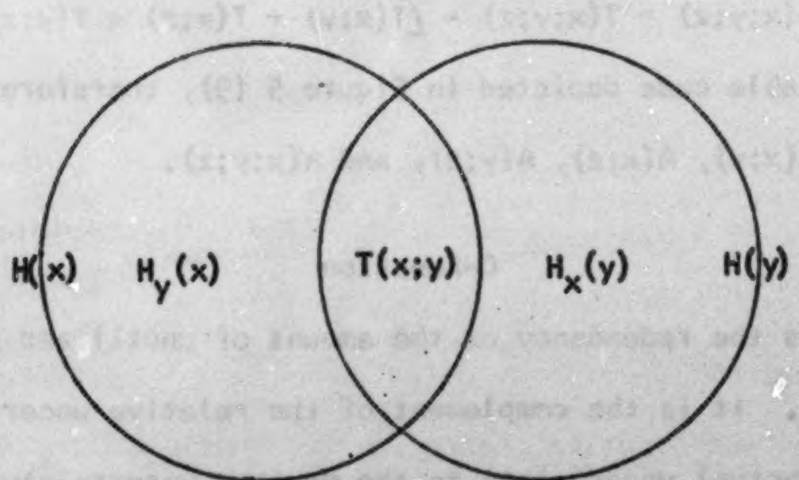
FIGURE 4



A: Input and Output Independent


H(x)
T(x;y)
H(y)
H(x,y)

B: Input and Output Equivalent


H(x)
H_y(x)
T(x;y)
H_x(y)
H(y)
H(x,y)

C: Input and Output Dependent but Non-equivalent

It follows that $T(x;y) = H(x) - H_y(x) = H(y) - H_x(y)$. Thus, $T(x;y)$ can be said to measure the reduction in the amount of information required to locate an element in x, if it has been located in y or vice versa; i.e. it measures information shared by x and y. T, therefore, can be said to measure relatedness.

A-Function

In ensembles of three or more classifications, the overall transmission of information or overall relatedness, T, can be partialled into fractions, because there may be not only information in common to or shared by two variables but also in common to or shared by three variables, four variables, etc. This measure of partialled transmitted information or relatedness is known as the 'A-function.'

For two variables, A is T, i.e. $A(x;y) = T(x;y)$. However, in the case of three variables there may be transmission or relatedness due to the three variables over and above that due to two variables. For three variables

$$A(x;y;z) = T(x;y;z) - [T(x;y) + T(x;z) + T(y;z)]$$

In the three variable case depicted in Figure 5 (9), therefore, $T(x;y;z)$ may be partialled into $A(x;y)$, $A(x;z)$, $A(y;z)$, and $A(x;y;z)$.

C-Function

C measures the redundancy or the amount of unutilized possibilities to carry information. It is the complement of the relative uncertainty which is the ratio of the actual uncertainty to the maximum uncertainty. With respect to the classification x, the relative uncertainty is given by $\frac{H(x)}{\text{Max } H(x)}$.

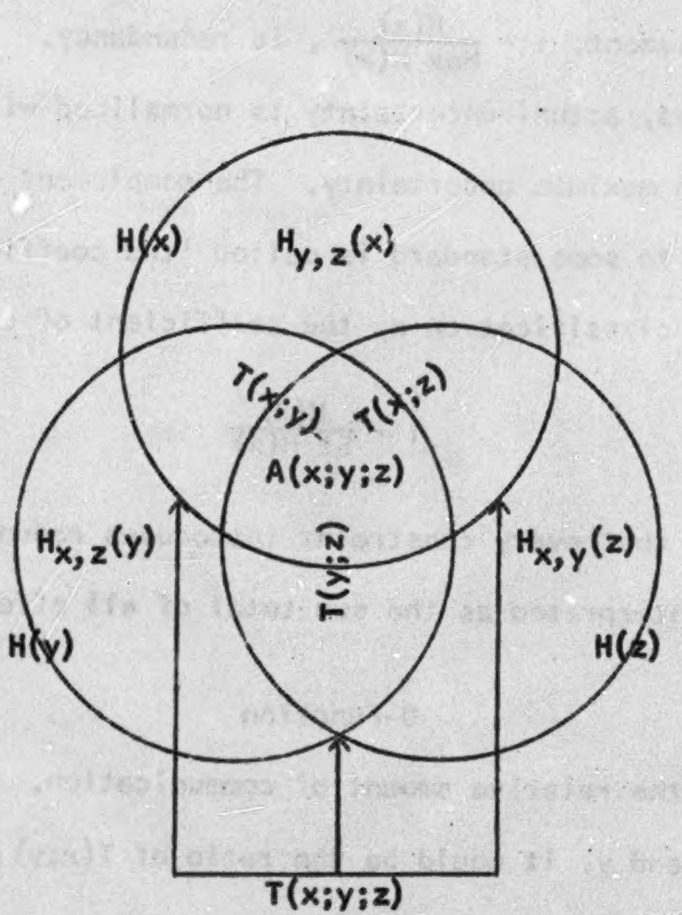

H(x)
$H_{y,z}(x)$
T(x;y)
T(x;z)
A(x;y;z)
$H_{x,z}(y)$
T(y;z)
$H_{x,y}(z)$
H(y)
H(z)
T(x;y;z)

FIGURE 5: Partialled Relatedness

The maximum H(x) or largest possible value of H(x) occurs when all states or alternatives are equiprobable. It follows that relative uncertainty is a measure of the degree to which the diversity in x is utilized to carry information. Therefore, its complement, $1 - \frac{H(x)}{\text{Max } H(x)}$, is redundancy.

In some cases, actual uncertainty is normalized with respect to some standard rather than maximum uncertainty. The complement of the actual uncertainty with respect to some standard is called 'the coefficient of constraint.' With respect to the classification x, the coefficient of constraint would be

$$1 - \frac{H(x)}{\text{St } H(x)}$$

Since it is obvious that every constraint introduces redundancy, the measure of redundancy can be interpreted as the sum total of all effects of all constraints.

D-Function

D measures the relative amount of communication. With respect to the classifications x and y, it would be the ratio of T(x;y) to H(x) or to H(y). In the first case it gives us the exhaustiveness of communication and in the second case the dependability of communication. The two cases

$$D(y:x) = \frac{T(x;y)}{H(x)}$$

$$D(x:y) = \frac{T(x;y)}{H(y)}$$

indicate that the D-function is asymmetric. ('The colon' denotes asymmetry.) $D(x:y) \neq D(y:x)$.

D is also a coefficient of constraint, and so measures relative amount of relatedness. Again with respect to the classifications x and y, the coefficient of constraint of y upon x would be

$$1 - \frac{H_y(x)}{H(x)}$$

and the coefficient of constraint of x upon y would be

$$1 - \frac{H_x(y)}{H(y)}$$

Channel Capacity

Channel capacity is the maximum information transmission or communication obtainable with a given channel, Max T. The channel capacity is important, because Shannon proved that for a channel, such as the one represented in Figure 3, IV, when the information of the source is less than the channel capacity, $H(x) < \text{Max } T(x;y)$, the equivocation, $H_y(x)$, can be reduced to any desired tolerance. See Figure 6. Shannon stated this theorem as follows:

> Theorem 11: Let a discrete channel have the capacity C and a discrete source the entropy per second H. If $H \leq C$ there exists a coding system such that the output of the source can be transmitted over the channel with an arbitrarily small frequency of errors (or an arbitrarily small equivocation). If $H > C$ it is possible to encode the source so that the quivocation is less than $H - C + \epsilon$ where ϵ is arbitrarily small. There is no method of encoding which gives an equivocation less than $H - C$. (10)

The way in which equivocation is reduced is to increase relatedness, and thus redundancy.

Efficient Communication

This presentation of information theory not only emphasized appropriate coding of messages (Shannon's Fundamental Coding Theorem) but also adequate

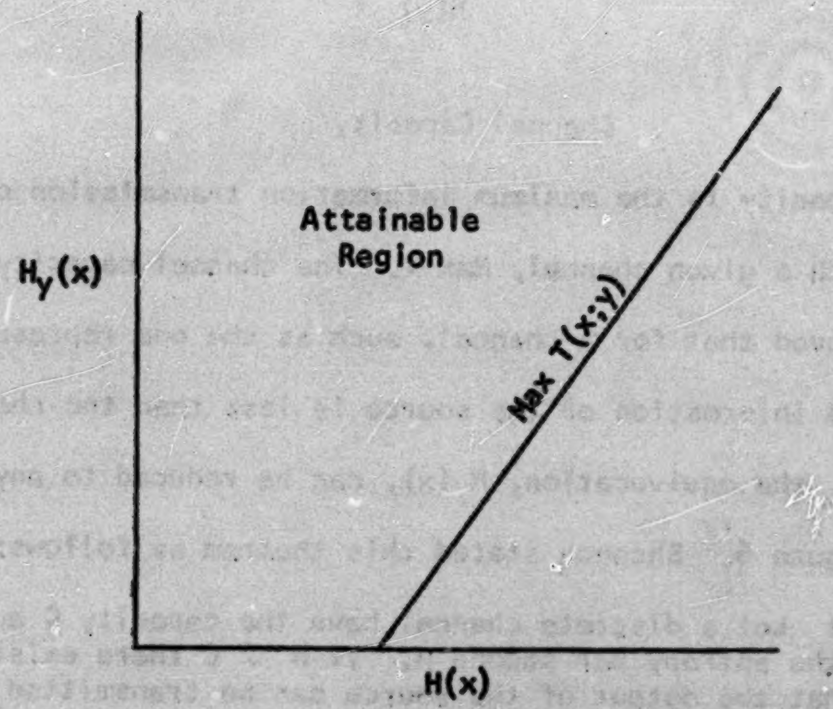

Attainable
Region
$H_y(x)$
Max $T(x;y)$
$H(x)$

FIGURE 6: Attainable Equivocation (10)

transmission of messages (Shannon's Limit Theorem for Information Transmission). Thereby what J. R. Pierce suggested (11) has been indicated; namely, that efficient communication is a matter of proper handling of redundancy--removal of some and addition of other redundancy. Too much redundancy means too little information, and too little redundancy means too little information.

III. THE EDUCATIONAL THEORY

Doubt Functions

The perspecitve of information theory leads pedagogists away from teaching as an immediate stimulus and student behavior as the observed response. It demands consideration of alternative possible stimuli and reponses. The usual T-E functional, E = f(T) where 'E' denotes effect in terms of student behavior and 'T' denotes a teaching, becomes interpreted as a statistical function. However, the perspective of information theory involves more. It is quite possible to take a statistical approach in regard to learning as Estes (12), Bush and Mosteller (13), and others have done and yet not utilize information theory as a model. The more is stated by Crossman as follows:

> Instead of a stimulus causing a reaction when the threshold is exceeded, we now think rather in terms of a signal which may be obscured by noise, providing the information needed to select a response. (14)

This more leads pedagogists away from emphasis upon the teaching as the "cause" of the student's behavior. It demands consideration of the student as active. Teaching becomes a basis for response selection. The prevailing distinctions between various types of learning--motor, verbal, concept formation, etc.--

become less important as the teaching-learning process becomes a problem-solving or inquiry process. To solve a problem or to inquire is to select a response.

Within the context of the teaching-learning process as a problem-solving process, doubt functions emerge. Where there is a problem, there are alternatives. Where there are alternatives, there is uncertainty and hence doubt. To solve the problem is to select a response, to come to certainty, to resolve a doubt. It is to fixate belief. (15) Where there is no problem, there are no alternatives. Where there are no alternatives, there is no uncertainty and hence no doubt. There may be no problem, because there already is a belief. But there also may be no problem, because there is ignorance. There is lack of awareness of alternatives. The certainty of the ignorant man is really no certainty. It is 0 of the 0 to 1 uncertainty continuum.

To speak of 'an uncertainty continuum' means that there can be more or less doubt. If the problem is more complex, contains more alternatives, then there is more doubt. Furthermore, the uncertainty is greatest when all the alternatives are equiprobable. If, however, alternatives are not equiprobable, they are related or condition one another, then the uncertainty is less. Consequently, one may say that the more organized a problem is, the less doubt there is. Since the amount of uncertainty is taken to be the amount of information; the more complex a problem is, the more information it contains, and the more organized a problem is, the less information it contains.

To summarize, doubt functions are defined with respect to problems. Problems are sets of alternatives and their probabilities. (16)

$\mathcal{X}$-Function

The basic doubt function will be designated by '$\mathcal{X}$.' The measure of $\mathcal{X}$ will be stated exactly as the measure of H. Consequently, the precise statements of the H-function in the model become the precise statements of the $\mathcal{X}$-function in the theory. This transition is justified, even though the measure of H depends upon a probability context which involves one in an infinite sequence and supposed knowledge of the parameter values of the statistical process. Fano has demonstrated that the statistical characteristics assumed a priori can be different from the observed frequencies without the efficiency of coding or transmission being lowered very much. (17)

$\mathcal{X}$, therefore, would be the average doubt or the average number of selections necessary to solve the problem. The problem or set of alternatives can be mapped into sequences of one-bit choices. The number of bits gives us the number of selections.

The number of selections given by $\mathcal{X}$ is the minimum required, although a problem may be treated in an inefficient manner. More selections than are required might be made. For example, if one is to solve a problem as to the classification of an element according to the reactions and properties of its ion, it would be inefficient indeed to proceed through selection among each of the possible reactions and properties of ions. Rather the efficient procedure would be the selection in terms of certain reactions and properties which separate the ions into groups of ever-decreasing size. One proceeds from the general to the specific. Within the curriculum of chemistry, there is a course that deals with such efficient coding, i.e. qualitative analysis. Those of you that had "qual" remember that you were not simply in the "lab" to solve unknowns. There was an emphasis upon the minimal number of selections necessary to solve an unknown. Teaching of qualitative analysis not only consists in marking off the problems but also in delineating efficient selection processes.

$\mathcal{X}$-Function and Problem Solving

The teaching-learning process, as already indicated, is taken to be a problem-solving process. The problem-solving system can be viewed through the perspective of a communication system. The problem to be solved would be the source; the problem as solved, the destination; and the problem-solver and his environment, the channel.

Utilizing the above parallel and the one between the $\mathcal{X}$-function and the H-function, the $\mathcal{X}$-function may be placed in the context of problem-solving. The problem to be solved would constitute the input of the system, $\mathcal{X}(x)$; the problem as solved, the output of the system, $\mathcal{X}(y)$; and the problem-solver and his environment would determine whether $\mathcal{X}(x)$ is decreased by $\mathcal{X}_x(y)$ or increased by $\mathcal{X}_y(x)$ or both.

$\mathcal{X}(x)$ can be viewed as the stimulus doubt. The role of the teacher, then, would be producing in the classroom doubt which could be a basis for the learner to engage in a selection process. Teaching would be the formulating of problems or sets of alternatives. One could argue that this is the sole teaching task, even though in discussing doubt functions I emphasized the delineation of efficient selection processes. Such delineation might be approached problematically, and so reduce to problem formulation. Finally, this view of teaching does not rule out teaching oneself. Perhaps this is what is desired and desirable. If so, the teacher who is not the learner (as is usually the case in the formal setting of the school) should strive to make the learner his own teacher (as well might be the case in the non-formal setting outside of the school). To make the learner his own teacher is to make him a problem formulator. However, this too entails teaching as defined above, i.e. the formulation of problems. Now, of course, they are problems about problem formulation.

$\mathcal{X}(y)$ can be viewed as the response doubt. The role of the learner, then, would be the reduction of doubt through selection among alternatives. Learning would be the passage from doubt to belief or the solving of problems. The beliefs or solutions would be the learnings.

The learner and his environment can add doubt to the problem as presented or decrease the doubt in the problem. That is to say, the problem can be rendered more complex or simplified. Since the learner has residues of past experiences, these schemas (18) could increase or decrease the doubt depending upon the degree of dissimilarity of the solution of the presented problem to the schemas. There must be just the right degree of dissimilarity. As the dissimilarity increases beyond this value, doubt is increased. As the dissimilarity decreases in relation to this value, doubt is decreased. Complete similarity means no doubt at all. There is no problem. Stated differently, the schemas could introduce more complexity or could lead to more organization. In either case, the problem as presented would not be the problem as solved. The environment of the learner in the formal setting of the school also can increase or decrease doubt. The classroom constitutes a physical and human context in which a given teaching-learning process or problem-solving can take place. The problem, whether spoken or written or presented in another way, does pass through a physical context, e.g. sound is transmitted through the atmosphere. We rarely are bothered by classrooms with such inadequate acoustical properties that the sound is distorted, or with other aspects of the physical context which increase or decrease doubt. Lighting and other like matters are for the most part under our control. When it comes to the human context, however, the situation is more difficult to control. There is a structure of relations among the persons'making up the classroom group. (19) Consequently, the problem very often is not presented directly to the learner by the teacher but passes through other learners to the learner. The problem, hence, may be radically altered or even eliminated. The task of the teacher, then, becomes the formulation of the problem in terms of the learner and his environment, so that there is a problem for the learner and he can face it as presented. In some cases, one might adjust the environment rather than adjust the problem to the environment. For example, the classroom grouping could be altered. It is evident, thus, that the teacher also has a role in controlling the environment.

$\mathcal{T}$-Function

The amount of doubt common to both the problem as presented and as solved would be the degree to which the doubt is transmitted. It is a measure of the gain in certainty or degree to which the problem as presented is solved, and will be designated by '$\mathcal{T}$.' Since the role of the teacher is to formulate the problem so that the learner can solve it as presented, $\mathcal{T}$ would be the measure of teaching. $\mathcal{T}$ parallels T in the model. Taking $\mathcal{X}(x)$ to be the measure of the stimulus doubt or problem as presented, $\mathcal{X}(y)$ the measure of the response doubt or the problem as solved, $\mathcal{X}(x,y)$ the measure of doubt in both problems and $\mathcal{T}(x;y)$ the measure of doubt common to both problems, then it follows:

1. there is complete teaching, if $\mathcal{T}(x;y) = \mathcal{X}(x,y) = \mathcal{X}(x) = \mathcal{X}(y)$,
2. there is incomplete teaching, if $\mathcal{T}(x;y) = \mathcal{X}(x) + \mathcal{X}(y) - \mathcal{X}(x,y)$, and
3. there is no teaching, if $\mathcal{T}(x;y) = 0$.

The problem as presented, the stimulus doubt may, and usually does, involve conditional probabilities. That is to say, if one solves the presented problem, consideration of more than one classification--e.g. of y as well as x--is required, and if one has found the partial solution in terms of one classification, then the doubt remaining as to the other classifications is reduced--$\mathcal{X}(x) - \mathcal{X}_y(x) = \mathcal{X}(y) - \mathcal{X}_x(y)$. This obtains, because doubt in regard to one aspect of the problem is related to doubt in regard to the other aspect of the problem. The problem is organized. With this shift of perspective where x and y are variables within the stimulus rather than x being the stimulus variable and y the response variable, $\mathcal{T}$ can be taken also to be a measure of the degree of organization of the stimulus or presented problem. Through organization of the problem, the teacher can reduce doubt in order to taken into account the learner and his environment. Through this means, the problem as presented may be the problem as solved.

α-Function

If the problem is to be transmitted to more than one learner (there is more than one response variable in addition to the stimulus variable) or if the presented problem involves more than two classifications of alternatives (there are more than two variables within the stimulus); there is a possibility of commonality of doubt between two or more learners and what the teacher presents, or of relatedness between three or more alternatives. This possibility goes beyond the commonality of doubt or relatedness due only to two variables. Consequently, partitioning of commonality or relatedness where three or more variables are involved goes beyond the τ-function. This going beyond is indicated by 'α.' α parallels A in the model. Since a classroom group usually includes more than one learner and the learners usually condition one another's solution of the problem, and since problems as presented usually involve more than two classifications of alternatives; the α-function supercedes the τ-function. Multivariate informational (doubt) analysis usually is called for. (20)

ζ-Function

In presenting a problem, the doubt might not be its maximum. X might not be equal to Max X. Not all alternatives might be equiprobable. $\frac{X}{\text{Max } X}$ would indicate such relative doubt, and would measure the degree to which the diversity in the classification or classifications are utilized to carry doubt. By taking the complement of the relative doubt, the degree to which the diversity is not utilized to carry doubt would be obtained. This is known as redundancy, and will be designated by 'ζ.'

Max X would be in the case of curricular materials an unnatural standard. X should be normalized in terms of a natural standard. An example can best illustrate this contention. The English alphabet has 26 letters; thus the maximum uncertainty of the occurrence of a single letter would be

$$\log_2 26 = 4.7 \text{ bits.}$$

Due to unequal frequency of usage, the actual average uncertainty of a single letter, taken out of context, in a printed text is only 4.08 bits. The average uncertainty of a single letter within the context is only about 2 bits. (21) The coefficient of this intersymbol constraint, therefore, should be the complement of the ratio of 2 to 4.08, rather than 2 to 4.7. Redundancy would be the sum total of the effects of all the constraints. Returning to our English language example, Carson has determined that 81% of the internal constraint upon printed letters is due to words and the other 19% to additional context. (22) In regard to curricular materials it would be necessary to determine the standards and the coefficients of constraints. For example, the language of a given scientific discipline should have unequal frequency of usage of its letters (which letters, of course, number more than 26 due to introduction of mathematical "letters," etc.). The determination of this unequal frequency of usage would be the determination of one basis for normalization. What, then, would be the constraints? The fact that the letters of a scientific discipline are within a hypothetico-deductive system produces constraint. Surely, if the teacher is to organize the problem to reduce doubt so that it will take into account the learner and his environment, the way of introducing constraints and the amount of redundancy thereby introduced must be known. The fact that the problem is programmed does not free one from this task.

δ-Function

δ measures the relative amount of teaching. If $\mathcal{X}(x)$ is the measure of the problem as presented, $\mathcal{X}(y)$ the measure of the problem as solved, and $\mathcal{T}(x;y)$ the measure of the teaching, then

$\frac{\mathcal{T}(x;y)}{\mathcal{X}(x)}$ would give $\delta(y:x)$, the exhaustiveness of teaching, and

$\frac{\mathcal{T}(x;y)}{\mathcal{X}(y)}$ would give $\delta(x:y)$, the dependability of teaching.

If the teaching is exhaustive, then there is no more doubt in the problem as presented then in the problem as solved. The problem as solved is no more organized than the problem as presented. The learner and his environment have not introduced redundancy. If the teaching is dependable, then there is no more doubt in the problem as solved than in the problem as presented. The problem as solved is no more complex than the problem as presented. The learner and his environment have not subtracted redundancy. In order words teaching is exhaustive when $\mathcal{T}(x;y) = \mathcal{X}(x)$, dependable when $\mathcal{T}(x;y) = \mathcal{X}(y)$, and both exhaustive and dependable when $\mathcal{T}(x;y) = \mathcal{X}(x) = \mathcal{X}(y)$.

Just as a shift in perspective also made $\mathcal{T}$ a measure of the organization of the stimulus doubt or presented problem, in like manner the same shift in perspective makes δ a measure of relative organization of the stimulus doubt or presented problem. If x and y are taken to be classifications within the stimulus doubt, then $\delta(x:y)$ is viewed as the coefficient of constraint of x upon y and is given by

$$1 - \frac{\mathcal{X}_x(y)}{\mathcal{X}(y)}.$$

and $\delta(y{:}x)$ is viewed as the coefficient of constraint of y upon x and is given by

$$1 - \frac{\chi_y(x)}{\chi(x)}$$

Learning Capacity

Learning capacity is the maximum teaching obtainable with a given learner in a given environment. Learning capacity will be designated by 'Max $\chi(x;y)$.' It is important to determine learning capacities, since otherwise under- or over-teaching with their concomitant effects will take place.

If input is high in relation to the capacity of a system, the system will utilize adjustment processes to reduce the input. Negative feedback will occur. (23) In the case of a problem-solving system, if the stimulus doubt (problem as presented) is greater than the learning capacity, the problem faced by the learner will not be the problem as presented. The learner will reduce the stimulus doubt by neglecting some of it or by simplifying the presented problem through more organization. In severe cases of over-teaching, the student may cut off entirely the stimulus doubt. Such escape may vary from inattentiveness to truancy.

There is a possibility for handling over-teaching which permits facing the problem as presented. If a given learner relates to other learners, the overall learning capacity might be increased. The teaching, therefore, might be no longer over-teaching. In other words, group problem-solving might permit the handling of more doubt. In relation to our model, this would be utilization of multiple channels.

If input is low in relation to the capacity of a system, the system will utilize adjustment processes to increase the input. Positive feedback will occur. In the case of a problem-solving system, if the stimulus doubt (problem as presented) is less than the learning capacity, the problem could be faced as presented. However, learner behavior to increase the doubt in the stimulus would probably occur, e.g. the attention-getting behavior of the gifted student. On the other hand, the problem might not be faced as presented, if the under-teaching is too severe. The student may cut off entirely the stimulus doubt. Again such escape may vary from inattentiveness to truancy. Thus, this educational theory hypothesizes that inattentiveness or truancy or both may be associated with the gifted as well as the slow learner, where giftedness and slowness is relative to a given teaching.

There is yet another reason that determination of learning capacity is important. Knowing the learning capacity, the stimulus doubt can be formulated in such a manner that the subtraction of doubt or increase in redundancy introduced by the learner and his environment can be reduced to any desired tolerance. This follows from Shannon's Limit Theorem for Information Transmission stated in the model.

Efficient Teaching

Efficient teaching is neither under- nor over-teaching. It essentially entails organization of problems so that they are neither too simple (over-organized) nor too complex (under-organized). Organization of this nature can occur only if the teacher understands subject matter (the way it is put together or its constraints), the learner (his capacity in terms of past experiences or

his schemas), and the environment (the physical and human context of the classroom). Given this understanding, the control of subject matter and environment which results in presenting solvable problems will follow.

IV. SIGNIFICANCE OF INFORMATION THEORY

For a long time in educational circles there has been an emphasis on problem-solving. In the early part of this century, Dewey (24) urged that the teaching-learning process be so conceived; and since then, this urging has been repeated again and again. Consequently, this tentative educational theory must appear relevant and fruitful. Nevertheless, studies that support theory will be cited (25) and studies suggested by the theory will be indicated. In this manner, the significance of information theory as an educational theory model which leads to adequate speculation about educative phenomena will be substantiated.

To begin with, the proposed educational theory would provide the necessary precision and operational quality for adequate experimentation. It should overcome the confusion as to the meaning of 'problem-solving' which largely arises from its present rationale. As Hermanowicz has stated:

> **The rationale behind "the problem solving method" as a classroom procedure usually is given in the form of cognitive learning theory, democratic principles, and Dewey's philosophy of instrumentalism. . . . the teaching method of problem solving has been derived . . . from three or more different sources. (26)**

Not that I am rejecting democratic principles or Dewey's philosophy of instrumentalism, but I am asserting that 'problem-solving' is given precise meaning when it is reformulated through the perspective of information theory. This

has been seen, in part, by Novak who suggested a test of problem-solving ability based upon selection among alternatives. (27) Moreover, this reformulation permits operational specification of variables. The presented problem (teaching or stimulus) and solved problem (learning or response) can be specified in terms of doubt functions.

Suchman's inquiry training program (28) as well as Smith and Henderson's work in development of materials designed to develop critical thinking abilities and training of teachers in their use (29) are attempts to approach the teaching-learning process as a problem-solving process. However, both Suchman and Smith point up the limitations of their results. Suchman states that the scores of those trained in his program were not significantly different from those of the control groups. Smith and Henderson state that they could not describe or measure the teaching.

In Suchman's program, this tentative educational theory suggests that the stimulus or teaching in terms of the problem episode film and critique of the child's approach could be delineated in the context of a set of alternatives involving constraints and a coding process, that the test for response could likewise be delineated, and that the measure of the teaching or of the program could be taken as the commonality of stimulus doubt and response doubt.

In Smith and Henderson's training of teachers, this tentative educational theory suggests an approach to the logic and content of subject matter which would emphasize determination of standards for normalization and constraints. The subject matter, then, could be organized as problems which are solvable by the learner in the classroom. Teaching would be problem formulation in terms of learning capacity.

Besides the work of Suchman and of Smith and Henderson, Crowder's intrinsic programming should be mentioned. (30)(31) Essentially, this is a problem-solving approach. The tentative educational theory could be fruitful in dealing with the number of branching alternatives in relation to a problem presented to a given learner.

The task of delineating the problem is formidable indeed. Yet G. A. Miller's assertion (32) that information theory offers a methodology for quantifying organization has been substantiated, if only in a restricted way. Stimuli have been constructed to contain desired number of bits (amount of uncertainty) (33) and others could be constructed utilizing the quantitative methods of shape and pattern construction set forth by Attneave and Arnoult (34). It should be pointed out, nevertheless, that the stimuli involved are dots, lines, and the like. Surely such stimuli would not be of primary concern to the pedagogist. Also the task of optimizing the problem in the sense of maximizing the teaching is difficult. Again use of the information theory perspective has indicated that success is possible here. Already results in optimizing the information transmitted from various stimuli have proven of consderable value within the growing field of engineering psychology. (35)

Before completing this discussion of the significance of information theory, the relevance of the concept of learning capacity within the perspective of information theory should be indicated. James G. Miller's survey of the literature supports his stated hypothesis:

> The relationship of input to output is such that the output, measured in bits per second, rises practically linearly as input increases up to channel capacity. It then levels off and finally decreases, falling off sharply as a state of confusion is reached. (36)

The lowest curve in Figure 7 is an overload curve which illustrates the hypothesis. The teacher can over-teach.

This brief survey of the literature should have emphasized that the tentative educational theory does fit other formulations about educative phenomena, and, if used with these formulations, could enrich them and offer greater possibility for refinement toward adequacy through experimentation. Information theory is significant for the doing of educational theory.

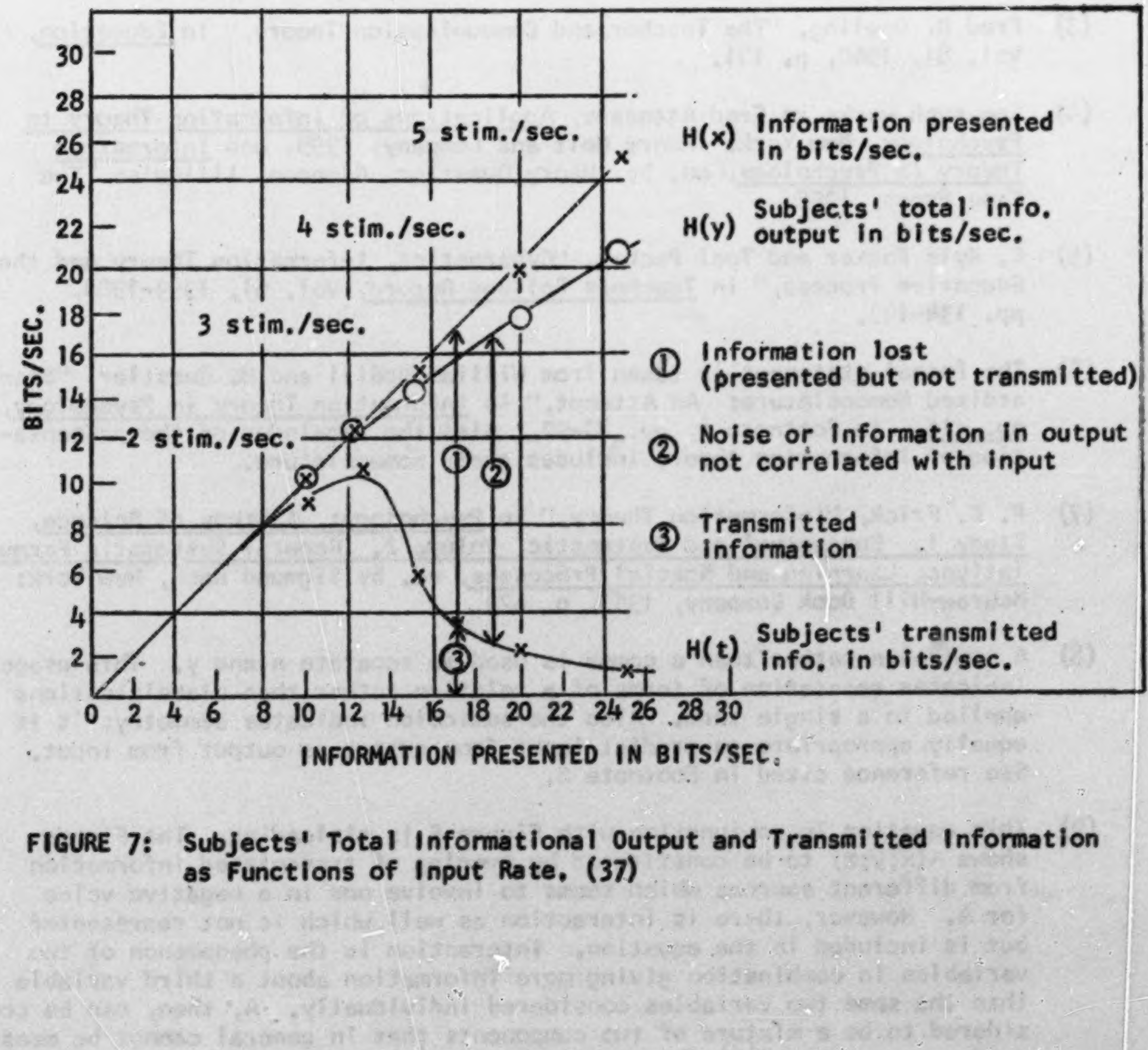


FIGURE 7: Subjects' Total Informational Output and Transmitted Information as Functions of Input Rate. (37)

FOOTNOTES

(1) The paper by Shannon was reprinted in The Mathematical Theory of Communication, Urbana, Illinois: The University of Illinois Press, 1949. See page 18.

(2) Ibid., p. 19.

(3) Fred R. Dowling, "The Teacher and Communication Theory," in Education, Vol. 81, 1960, p. 181.

(4) See such works as Fred Attneave, Applications of Information Theory to Psychology, New York: Henry Holt and Company, 1959, and Information Theory in Psychology, ed. by. Henry Quastler, Glencoe, Illinois: The Free Press, 1955.

(5) C. Kyle Packer and Toni Packer, "Cybernetics, Information Theory and the Educative Process," in Teachers College Record, Vol. 61, 1959-1960, pp. 134-142.

(6) The formal statement is taken from William McGill and H. Quastler, "Standardized Nomenclature: An Attempt," in Information Theory in Psychology, op. cit. in Footnote 4, pp. 83-92. Also the remainder of the presentation of information theory includes their nomenclature.

(7) F. C. Frick, "Information Theory," in Psychology: A Study of Science, Study 1. Conceptual and Systematic, Volume 2. General Systematic Formulations, Learning and Special Processes, ed. by Sigmund Koch, New York: McGraw-Hill Book Company, 1959, p. 625.

(8) A semicolon rather than a comma is used to separate x and y. This usage indicates separation of terms of a relation rather than classifications applied to a single term. Also the semicolon indicates symmetry; it is equally appropriate to predict input from output as output from input. See reference cited in Footnote 6.

(9) This equation in conjunction with Figure 5 is misleading. The Figure shows $A(x;y;z)$ to be constituted by overlap of transmitted information from different sources which seems to involve one in a negative value for A. However, there is interaction as well which is not represented but is included in the equation. Interaction is the phenomenon of two variables in combination giving more information about a third variable than the same two variables considered individually. A, then, can be considered to be a mixture of two components that in general cannot be measured separately: $A^{(+)}$ (interaction) and $A^{(-)}$ (transmission overlap). Interaction is usually greater, so that A is positive.

(10) Shannon, op. cit., pp. 39-40.

(11) Symbols, Signals and Noise, New York: Harper Brothers, 1961, p. 164.

(12) William K. Estes, "Toward a Statistical Theory of Learning," in Psychological Review, Vol. 57, 1950, pp. 94-107.

(13) Robert R. Bush and Frederick Mosteller, "A Mathematical Model for Simple Learning," in Psychological Review, Vol. 58, 1951, pp. 313-323.

(14) E. R. F. W. Crossman, "The Measure of Discriminability," in Quarterly Journal of Experimental Psychology, Vol. 49, 1955, pp. 323-332.

(15) Whether the problem is solved so that a correct selection or true belief emerges is important to be sure. In fact, it is of utmost importance. In doing educational theory, however, I am concerned to leave the value question or philosophical question open. I am dealing with the process of selection apart from criteria to judge its results. Such criteria introduce a value dimension.

(16) Whether the problems are significant or not is also a philosophical problem. The curriculum--group of problems to be solved--is surely a matter of providing opportunities to eliminate doubt in realms leading to actions of importance in man's life. Belief, as Peirce stated it, "puts us into such a condition that we shall behave in a certain way, when the occasion arises." ("The Fixation of Belief," in Values in a Universe of Chance, ed. by Phillip P. Wiener, New York: Doubleday Anchor Books, Doubleday & Co., Inc., 1958, p. 99.) It is for significant occasions that man needs to be in behavioral readiness.

(17) R. M. Fano, The Transmission of Information, Technical Report No. 65, Massachusetts Institute of Technology, Research Laboratory of Electronics, 1949.

(18) For a discussion of schema, see Occasional Paper 63-135, "An Educational Theory Model: Pharmacology and Pharmacogenetics."

(19) For a discussion centered about the structure of classroom groups, see Occasional Paper 62-125, "An Educational Theory Model: Graph Theory."

(20) Multivariate informational analysis is more general than multivariate analysis and requires no assumptions about metric properties of the criterion. See W. R. Garner and W. J. McGill, "Relation between Uncertainty, Variance, and Correlation Analysis," in Psychometrika, Vol. 21, 1956, pp. 219-228.

(21) These values are taken from Henry Quastler, "Information Theory Terms and Their Psychological Correlates," in Information Theory in Psychology, op. cit., p. 150.

(22) Daniel H. Carson, "Letter Constraints Within Words in Printed English," in Kybernetik, Vol. 1, 1961, pp. 46-54.

(23) For a discussion of input in relation to systems, see Occasional Paper 62-126, "An Educational Theory Model: General Systems Theory."

(24) How We Think, New York: D. C. Heath and Company, 1910.

(25) The excellent work of James Andris, graduate student in mathematics and research assistant on Project 1632, in abstracting such studies and also abstracting literature on information theory and its use in the social sciences is acknowledged.

(26) Henry J. Hermanowicz, "Problem Solving as Teaching Method," in Educational Leadership, Vol. 18, 1961, p. 305.

(27) Joseph D. Novak, "An Approach to the Interpretation and Measurement of Problem Solving Ability," in Science Education, Vol. 45, 1961, pp. 112-131.

(28) J. Richard Suchman, The Elementary School Training Program in Scientific Inquiry, Title VII Project Number 216, June, 1962.

(29) B. Othanel Smith, "Critical Thinking," in Recent Research and Developments and Their Implications for Teacher Education, Thirteenth Yearbook, American Association of Colleges for Teacher Education, Washington, D. C.: the Association, a department of the National Education Association, 1960, pp. 84-96.

(30) N. A. Crowder, "Automatic Tutoring by Means of Intrinsic Programming," in Automatic Teaching: The State of the Art, ed. by E. H. Galanter, New York: John Wiley and Sons, 1959, pp. 109-116.

(31) N. A. Crowder, "Automatic Tutoring by Intrinsic Programming," in Teaching Machines and Programmed Learning: A Source Book, ed. by A. A. Lumsdaine and R. Glaser, Washington, D. C.: National Education Association, 1960, pp. 286-298.

(32) "What is Information Measurement?" in American Psychologist, Vol. 8, 1953, pp. 3-11.

(33) See work such as that of I. Pollack and E. T. Klemmer, The Assimilation of Visual Information from Linear Dot Patterns, Air Force Cambridge Research Center: Technical Report, 54-16, July, 1954.

(34) F. Attneave and M. D. Arnoult, "The Quantitative Study of Shape and Pattern Perception," in Psychological Bulletin, Vol. 53, 1956, pp. 452-471.

(35) See work cited in Footnote 33 and other work such as that of C. W. Eriksen, Multidimensional Stimulus Differences and Accuracy of Discrimination, USAF: WADC Technical Report, 54-162, 1954.

(36) "Information Input Overload," in Self-Organizing Systems 1962, ed. by M. C. Yovits, *et al*., Washington, D. C.: Spartan Books, 1962, p. 63.

(37) From Klemmer and Muller in James G. Miller, *op. cit*. in Footnote 36, p. 65.

PRECEDING PAGE MISSING

ERRATA

p. ii:	l. 6:	'field-feature' not 'field feature'
p. iii:	l. 20:	'sent forth' not 'set forth'
p. 20:	l. 24:	'statement of Broad to follow' not 'statement to follow of Broad'
p. 26:	l. 9-10:	'statement' not 'statements'
p. 31:	l. 14:	'(methods)^{10},' not '(methods),^{10}'
p. 60:	l. 38:	'RETURN (at' not 'RETURN ((at'
p. 64:	last line:	'represented' not 'represnted'
p. 108:	l. 11:	'relation' not 'relational'
p. 135:	Footnote 5, l. 2:	'especially' not 'espeically'
p. 137:	Footnote 23, l. 1:	'Bertram' not 'Betram'
	Footnote 24, l. 1:	'Bertram' not 'Betram'
p. 138:	Footnote 32, l. 2:	'1951,' not '1951.'
p. 144:	9, l. 1:	'subsystem' not 'sub-system'
p. 170:	l. 15-16:	'principles of demand and equal advantage' not 'Principles of Demand and Equal Advantage'
p. 180:	l. 1:	'justify' not 'justifies'
p. 184:	l. 6:	'Prospective, the' not 'Prospective the'
p. 232:	l. 3:	'explain radiation' not 'explain, radiation'
	l. 15:	'0' not 'o'
p. 234:	l. 18:	'line' not 'lind'
	l. 23:	'affect' not 'affects'
p. 236:	Equation 1:	'$q_2,...,q_n$' not '$q_2,...q_n$'
p. 238:	l. 3:	'one' not 'one'
p. 239:	Equation 7b:	The second large parenthesis sign should be just before the psi function.
p. 241:		'x' not 'X'

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p. 243:	Equation 7b:	The second large parenthesis sign should be just before the psi function.
p. 245:	l. 1:	'When' not 'when'
	l. 11:	'Schroedinger type' not 'Schroedinger-type'
p. 246:	l. 17:	'Figure 6' not 'Fibure 6'
	l. 19:	'Heisenberg' not 'Heinsenberg'
p. 247:		'f'_b' not '$f_b{}^{1}$'
p. 248:	Equation 17:	'q' not 'g'
	l. 21:	'that, no' not 'that no'
p. 255:	Equation 27b:	1 should be inserted after equal sign and before minus sign. 'Ln' denotes natural logarithm.
p. 257:	l. 13:	'0→a' not 'o→a'
p. 259:	l. 1:	'equation is' not 'equations are'
p. 261:	Equation 41:	'COT' not 'TAN'
p. 265:	l. 18:	'withhold' not 'withold'
p. 267:	l. 5:	'Disturbing' not 'Distributing'
	l. 9:	'disturbing' not 'distributing'
p. 271:	l. 4:	'arithmetic' not 'arithemetic'
p. 272:	Equation 46:	1 should be inserted before minus sign. 'Ln' denotes natural logarithm.
	l. 18:	'respectively. (25) In the Figures' not 'respectively. In the figures'
p. 279:	Footnote 3, l. 4:	'system at' not 'system, at'
p. 302:	l. 8:	'$(H = \log_2 8 = 3)$' not '$(H = \log_2 8 = 3.)$'
p. 312:	l. 18:	'equivocation' not 'quivocation'
p. 314:	l. 8:	'perspective' not 'perspecitve'
p. 317:	l. 6:	'Problem-solving' not 'Problem Solving'
p. 320:	l. 23:	'take' not 'taken'
p. 326:	l. 9:	'support the theory' not 'support theory'
p. 328:	l. 17:	'considerable' not 'consderable'